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ABSTRACT

Five units are designed to provide an opportunity for in-depth, technical analysis in the fields of energy, economics, and the environment. In an effort to move upper elementary and secondary students beyond general awareness, activities call for the application of numbers where typically only vague generalities are discussed. Within each chapter, activities are written on three levels of skill development: (1) awareness level, where students identify and analyze concerns by qualitative means; (2) transitional level, where they refine and extend these abilities to quantitative analysis; and (3) operational level, where they apply these techniques in more complex situations. Activities within each unit not only progress in skill level difficulty but also in grade level ranging from fourth to twelfth grade. Drawing upon many subject areas, these interdisciplinary activities focus on five topics: human energy, electricity, space heating, solar energy, and bioconversion. Each unit includes an overview, extensive teaching notes, worksheets, data sheets, and six or more activities. (Author/DC)

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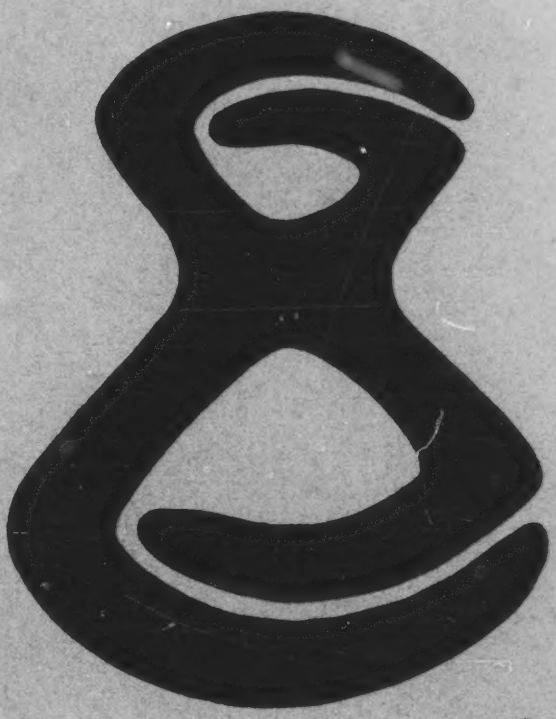

COUNTING ON ENERGY

by

Randolph R. Tully, Jr.
with
D. Chris Reese

Project E3
Energy, Economics, and the Environment

SE 035 614

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Energy, Economics, and the Environment

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PREFACE

Project E3 (Energy, Economics, and the Environment) was funded as a curriculum development project during the school years of 1976-77, 1977-78, and 1978-79. Two major activities of the project included Local Action Programs (LAPs) and teacher training workshops. Over the three year life of the project, 35 LAPs were conducted in Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties of southeastern Pennsylvania. Each of these programs was tailored to the needs and desires of the teachers and students who ran the programs. During the summers, five teacher training workshops were conducted. These provided an opportunity to introduce and refine a number of activities developed by E3 staff.

The activities in this book are a compilation of some of the more successful activities used by the LAPs and teachers in E3 workshops.

ACKNOWLEDGEMENTS

This guidebook could not have been completed without the help of many people. All the teachers and students in the 35 E3 Local Action Programs deserve much credit. It was their willingness to develop and use a wide variety of new activities and techniques that lead to many of the activities included in this guide. Special thanks go to the following teachers whose project reports are included in the text of this guide: Sarah Ziegler, Bob Malkovsky, Sandra Bahorik, Nicholas Ignatuk, Jim Wakefield, Jacquelyn Blum, and Terry Burlingame. Thanks also go to the many teachers in our workshops who have given us invaluable feedback on the utility of particular activities.

All of the E3 staff, past and present, have been very helpful in seeing this guide to completion. Jeff Clark, Jeff Cope, and Al Sexton have willingly critiqued various activities as they have been revised again and again. Matt Hickey has readily provided the time needed to produce and refine this material. Chris Reese provided several of the activities that appear here; his name is at the top of his contributions.

Finally, Janet Gift's efforts have been greatly appreciated. She has tirelessly typed and retyped until all the words and charts finally fit the pages.

Thank you all for what will hopefully be a useful guide.

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INTRODUCTION

This activities guide is not intended to completely cover the whole range of possibilities in the field of energy, economics, and the environment. Nor is it designed to meet the needs of students at all grade levels, nor of all abilities. Rather it is a finite collection of activities which only hint at the possibilities of a discrete number of topics. When Project E3 began, there seemed to be many emerging curricula and activity guides written on an introductory, non-technical level. What we have attempted here is to provide technique which will allow the student investigator to progress beyond awareness to the application of more rigorous analysis of real situations. Many of our activities apply numbers where typically only vague generalities are discussed. Most of the activites are designed for the upper elementary or high school student. Even so, most can be adapted for the lower grades. The Skill/Grade/Discipline Suitability chart in the Appendix should help you to quickly find activities to match the abilities of your own students.

The activities have been organized into 7 major topic areas: human energy; transportation; electricity; space heating; solar energy; bioconversion; and environmental impact. Each topic has several activities covering a range of grade and skill suitabilities. Typically the earlier activites in a chapter are those most suitable for the lower grades. Each chapter begins with a brief introduction and quickly moves to provide teaching notes on the activities which follow. Some of the activities are worksheets or information which the students could use directly, others are data sheets which might be used as whole class activities, and still others are intended primarily for teacher use. You know your own students and will have to decide how best to apply any particular activity. Do-it-yourself approaches are strongly encouraged. Your teaching style, the curricular requirements of your school, the interests of your students, and other factors will all impact on the usefulness of any one of these activities. Consider this material as a starting point and modify till your needs are satisfied.

Within each chapter you will find activities written on three levels of skill development: the awareness level; the transitional level; and the operational level. By knowing the developmental level of your students, you will be better able to select appropriate activities. Awareness activities begin the process of identification and analysis of student concerns by qualitative means. Transitional activities refine and extend these abilities to quantitative analysis. At the operational level, students begin to apply these techniques in more complex situations. Often the awareness and transitional activities can be completed in one or two class periods. The operational projects, however, typically require attention over an extended time period. Ideally, students progress from the awareness level, through the transitional level, to the operational level.

Following is a list of process skills organized by the activity levels to which they apply:

Awareness Level
1. observing
2. categorizing
3. comparing (qualitative)
4. measuring
5. inferring
6. questioning

Transitional Level
1. comparing (quantitative)
2. predicting
3. data collection
4. data processing
5. data evaluation
6. formulation of hypotheses

Operational Level
1. problem recognition
2. problem definition
3. problem analysis
4. evaluation of alternatives
5. implementing a course of action (using the data)

Throughout an activity or a broader project, student involvement should be of paramount concern. To whatever extent possible, students should be given an opportunity to learn not only facts but should be able to develop skills at planning, implementing, and evaluating their own progress. Such an approach should lead to fuller and more willing student participation. The feeling of personal "ownership" of a program can be a boon to improved student discipline, and provide an optimal learning atmosphere.

These activities should not be considered complete and able to stand alone. Each should be used in the broader context of the rest of your studies. To whatever degree possible, these activities should be interrelated with other activities, other projects, and other disciplines. Especially at the operational level, interdisciplinarity, team teaching, or cooperative sponsorship of a project can be the best approach. Please be willing to adapt, modify and mold these techniques to your own needs.

As you progress from activity to activity you will find the metric system in use in some situations and the English system used in others. The eclectic approach is largely a reflection of our times. Builders know BTU's, nutritionists talk about kilocalories, electricity is metered in kilowatt-hours, Americans know about horsepower, wood comes in cords, and kilometers still confuse many people. If you want to convert to joules, or lumens, or centimeters, see the Unit Conversions tables in the Appendix.

Above all, have fun!

Human Energy

What better place is there to begin a study of energy than with ones own body? The student has already accumulated a wealth of qualitative experience and knowledge about his personal energy needs, and should easily be able to build on that base with the more quantitative activities which follow. These activities may help you to develop a feeling for some basic energy concepts such as horsepower and the calorie.

TEACHING NOTES:

Pumping Iron (Hemoglobin Style)

We begin with a very simple activity. It is universally known that some activities make ones heart beat faster than other activities. Here we start the quantification process by counting those beats. By collecting, recording, and analyzing data we begin to look more analytically at a commonplace phenomenon.

Human Horsepower Contest

Just how much horsepower can one human deliver? We are not looking for Charles Atlas; rather our goal is to more clearly differentiate the concepts of energy and power. Energy is simply defined as the ability to do work; while power is the rate at which that work is done. Our work is to move mass, that is, to move a human through a vertical distance. One of the most commonly available places to do that is a stairway. Climbing a stairway does involve some lateral movement, but the vertical climb requires the most energy and we'll simply disregard the lateral fraction. A steep hill, or a ladder, or a suspended rope could also be used.

One mechanical measure of power is the horsepower. This is conveniently defined as the power required to lift 550 lbs., 1 foot high, in 1 second. If you weight 225 lbs. and climb 2 feet high in 1 second, you've exerted an average of 1 horsepower throughout that second. In our stairway example, you'll need to know the height of the climb (h, in feet), the weight of the climber (w, in pounds), and the time length of the climb (t, in seconds). Horsepower output is calculated as $h \times w \div t \div 550$.

Since power is a rate of energy use we now can calculate a total amount of energy used. For human energy, the common measure is the kilocalorie. One calorie is the amount of energy needed to raise the temperature of one gram of water one degree celsius. A kilocalorie is 1,000 calories. Just to confuse things, the "calories" referred to in diet books are really kilocalories as far as physicists are concerned. For more confusion, kilocalories are sometimes called Calories; note the capital "C". A kilocalorie can also be defined as 0.00156 horsepower hours (1.56×10^{-3} Hp hr), or 5.6 horsepower seconds (60 sec/min x 60 min/hr X 1.56×10^{-3} Hp hr = 5.6 Hp sec). Now if we multiply our power output (Hp), by the time it was exerted (t, in sec), and divide by 5.6 Hp sec, we will get our total

energy consumption in kilocalories (C = Hp x t ÷ 5.6 Hp sec).

To calculate an amount of food required we only need to know the caloric content of some particular food. Granulated sugar, for instance, contains approximately 15 kilocalories per teaspoon. Our calculation then becomes sugar used = C consumed ÷ 15 C/tsp.

Recognizing the wide range of student abilities, it is suggested that they be allowed to set their own paces on the climb. Our "students" are sometimes over 60 and an over-exerted climb could present real medical problems. Any climb at all, whether it takes 6 seconds or 6 minutes, can be used to calculate power output. In fact, interesting comparisons could be made if each individual made several trips, some fast, and some slow.

Human Energy Needs

In today's dieting world, calorie counting seems to be a major recreational pastime. Unfortunately, the counting of calories does not use very many calories. With this activity we will attempt to calculate the amount of energy consumed by an individual during one particular day. This energy consumption can be categorized into three major components: basal metabolism, energy needed for daily activities, and energy needed for the internal processing of food.

Basal metabolism includes those bodily functions without which life would be impossible, including: respiration, circulation, glandular activity, cellular metabolism, and maintenance of muscle tonus and body temperature. Accurate measurement of basal energy needs requires fairly sophisticated sampling procedures and equipment. An individual's basal rate can be simply approximated, though. For persons with average body build, we can estimate basal needs as 1 kcal/kg of body weight/hr. As an individual tends toward obesity or leanness this approximation becomes increasingly less accurate.

It is axiomatic that the more active person has a greater energy requirement. The fact sheet which follows includes a table estimating the caloric needs of a variety of common activities. These requirements are measured in kcal/kg/hr. The student is asked to maintain an activity diary for one day. The length of time of each activity must be recorded. Personal daily energy requirements for discreet activities can now be calculated by multiplying the length of time (in hours) by the individual activity requirement (in kcal/kg/hr). These component amounts can now be totalled, then multiplied by the person's body weight (in kg) to yield a total of that person's daily caloric expenditures due to his activity level.

The third major area of energy utilization involves the ingestion of food. Typically this amounts to approximately 10% of the total of the basal and activity energy needs. The grand total energy consumption can now be calculated by multiplying the sum of the basal and activity needs by 1.1.

Now that it is known how many kilocalories were burned in a day, the question may arise as to how much was eaten. If the students don't ask, you should. The students can now make a list of all goods and amounts eaten on that same day. By consulting any of the many popular calorie counting booklets,

each student can calculate a personal total of kilocalories ingested. Remember that the "calories" mentioned in diet books are really kilocalories. Comparison of kilocalories ingested to kilocalories burned will show whether or not an individual has gained or lost on one particular day. This gain, loss, or balance can be initially read in kilocalories. For every 3,500 unneeded kilocalories an individual consumes, that person will gain 0.5 kg (1 lb.) of body weight. Undereating by 3,500 kilocalories results in the loss of .05 kg (1 lb.).

What's In The Package?

Here we begin to develop an understanding of the enormous amount of non-food energy involved in providing the food energy we all need. On the average it takes more than 7 kcal of fossil fuel energy to provide 1 kcal of food energy in a form that the American public will accept. As a group, processed fruits and vegetables require 16 fossil kilocalories for each food kilocalorie they provide; while fresh vegetables require about 5 fossil kilocalories for each food kilocalorie.

This activity will help the students to analyze a portion of that fossil fuel contribution: packaging. Students are asked to bring an item of packaged food to the classroom (a box of spaghetti, a "twinkie", a can of diet soda, etc.). Two computations are made: the kilocalorie content of the food and the kilocalories involved in the manufacture of the packaging. It will be necessary to have a relatively sensitive balance or scale so that the individual items can be weighed.

Waste Not, Want Not and Project POWER

These are both operational level projects. As such they require time and committment beyond the single class period. The descriptions included here are the final reports as submitted by the teachers leading the projects. Waste Not, Want Not was a program run by Sarah Ziegler, a home economics teacher at North Brandywine Junior High School in Coatesville, Pennsylvania. The high point of the project was a "Food Recycling Center" in the school cafeteria. Bob Malkovski ran Project POWER at Ridley Senior High School in Folsom, Pennsylvania. Their interest was also cafeteria food waste but their tact was to grow edible algae on specially processed waste.

Pumping Iron (Hemoglobin Style)

Everything you do, from sleeping, to jumping, to thinking, requires energy. The energy you are using is coming from the food you ate this morning, or sometime in the past. In order for your body to use that stored chemical energy, you must "burn" those food chemicals by combining them with oxygen from the air. That oxygen first travels through your nose or mouth to the lungs where hemoglobin (a chemical containing iron in the blood) picks it up. The blood and its hemoglobin then travel to all parts of your body to take the oxygen where it's needed. The harder you work; the more energy you need. The more energy you need, the more oxygen you need. The more oxygen you need, the more blood you need. The more blood you need, the faster your heart pumps. And you can measure that by counting your pulse. One easy way to count your pulse is to feel your left wrist with the middle two fingers of your right hand. The best spot is on the inside of the wrist near the base of the thumb. Count the number of beats in one minute. On the right are a few suggestions of when to count your pulse. What others can you think of?

EVENT	PULSE RATE (beats per minute)
falling asleep	_____
awakening	_____
watching TV	_____
walking	_____
running	_____
climbing stairs	_____
sitting	_____
standing	_____
eating	_____
talking	_____
when frightened	_____
when upset	_____
when angry	_____
when sad	_____
when happy	_____
others:	
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Questions:

-What activity gives you the highest pulse rate?

-When is your pulse the slowest?

-Do your moods affect your pulse?

-How does your pulse compare to other people?

Human Horsepower Contest

Purpose: To calculate the average horsepower output of a human over a relatively short period of time.

Equipment:
measuring tape or yardstick (calibrated in feet)
bathroom or doctor's scale
stopwatch or watch with second hand
2 or more flights of stairs

Procedure:
1. Measure total height of climb in feet (H).
2. Weigh each contestant in pounds (W).
3. Time each contestant's climb in seconds (T).
4. Calculate average horsepower output (Hp).

1 Hp = 550 ft lbs/sec
therefore:

$$Hp = \frac{H \times W}{550 \times T}$$

example:
H = 93'
W = 170 lbs
T = 27 sec

$$Hp = \frac{93 \times 170}{550 \times 27} = 1.06$$

Questions:
1. What advantages or disadvantages does a heavier person have?
2. How would carrying a weight affect a person's performance?
3. Would a longer or shorter climb affect a person's average output?
4. Does this technique account for all of an individual's power output?
5. Can you calculate the energy consumed (in kilocalories, C) in one climb?

1 C = 1.56×10^{-3} Hp hr
and
60 sec/min x 60 min/hr = 3600 sec/hr
therefore:

$$C = \frac{Hp \times T}{3600 \text{ sec/hr} \times 1.56 \times 10^{-3} \text{ Hp hr}}$$

therefore:

$$C = \frac{Hp \times T}{5.6 \text{ Hp sec}}$$

example:
Hp = 1.06 Hp
T = 27 sec

$$C = \frac{1.06 \times 27}{5.6} = 5.1 \text{ C}$$

6. How much sugar (S) must be consumed to fuel one climb?

1 tsp granulated sugar contains 15 C
therefore:

$$S = \frac{C}{15 \text{ C/tsp}}$$

example:
C = 5.1 C

$$S = \frac{5.1}{15} = .34 \text{ tsp}$$

7. If Vasili Alexeev lifts 550 lbs 6 feet in the air and it takes 3 seconds, what is his average horsepower output?

Human Energy Needs Fact Sheet

Total human energy needs are primarily dependent upon an individual's basal metabolic rate, ones level of activity, and the calorie requirements of food ingestion. An approximation of ones basal metabolic rate can be calculated by assuming the expenditure of 1 kcal/kg of body weight/hour. Energy consumed by activity can be estimated by using the table below, knowing one's body weight, and estimating time lengths for each activity. The overall energy requirements for food ingestion amount to approximately 10% of the sum of the basal metabolic rate plus the activity total. Therefore, total energy needs can be calculated as: (basal metabolism + activity total) x 1.1.

Energy Cost of Activities Exclusive of Basal Metabolism and Influence of Food

Activity	kcal/kg/hr	Activity	kcal/kg/hr
Bicycling (century run)	7.6	Rowing in race	16.0
Bicycling (moderate speed)	2.5	Running	7.0
Boxing	11.4	Sawing wood	5.7
Carpentry (heavy)	2.3	Sewing, hand	0.4
Cello playing	1.3	Sewing, foot-driven machine	0.6
Crocheting	0.4		
Dancing, foxtrot	3.8	Sewing, motor-driven machine	0.4
Dancing, waltz	3.0		
Dishwashing	1.0	Singing in a loud voice	0.8
Dressing and undressing	0.7	Sitting quietly	0.4
Driving automobile	0.9	Skating	3.5
Eating	0.4	Sleeping	+
Fencing	7.3	Standing at attention	0.6
Horseback riding, walk	1.4	Standing relaxed	0.5
Horseback riding, trot	4.3	Stone masonry	4.7
Horseback riding, gallop	6.7	Sweeping with broom, bare floor	1.4
Ironing (5-pound iron)	1.0		
Knitting sweater	0.7	Sweeping with carpet sweeper	1.6
Laundry, light	1.3	Sweeping with vacuum sweeper	2.7
Lying still, awake	0.1	Swimming (2 mph)	7.9
Painting furniture	1.5	Typewriting rapidly	1.0
Paring potatoes	0.6	Violin playing	0.6
Playing ping-pong	4.4	Walking (3 mph)	2.0
Piano playing (Mendelssohn's songs)	0.8	Walking rapidly (4 mph)	3.4
		Walking at high speed (5.3 mph)	9.3
Piano playing (Beethoven's "Apassionata")	1.4		
		Walking downstairs	++
Piano playing (Liszt's "Tarantella")	2.0	Walking upstairs	+++
		Washing floors	1.2
Reading aloud	0.4	Writing	0.4

Adapted from Introductory Nutrition, H.A. Guthrie, Mosby Co., St. Louis, 1979

\+ Assume that sleep requires no energy beyond basal needs.

++ Allow 0.012 kcal/kg for an ordinary staircase with 15 steps without regard to time.

+++ Allow 0.036 kcal/kg for an ordinary staircase with 15 steps without regard to time.

Human Energy Needs Worksheet

Name_____

Weight_____kg (1 lb = 0.454 kg)

1. Basal Metabolism:

1 kcal/kg/hr is an average human basal metabolic rate, therefore:

1 kcal x _____kg x 24 hrs/day = _____kcal/day
(your weight) (B)

2. Activity Needs:

Activity	Time (hr)	X	Energy Cost: kcal/kg/hr (from data sheet)	= kcal/kg
TOTAL =	24 hrs		TOTAL kcal/kg =	(C)

Total Activity Needs:

_____kcal/kg x _____kg = _____kcal/day
(C) (your weight) (A)

3. Total Needs:

basal metabolism (B) + activity needs (A) + effect of food ingestion (10% of B + A) = total energy needs
therefore:

(_____ + _____) x 1.1 = _____kcal
(B) (A)

What's in the Package?

by Chris Reese

A. What's in the package

1. What is the net weight of the food?
2. How many kilocalories could be provided by the food? Sometimes this information is printed on the package, otherwise the use of a kilocalorie table is necessary.

B. What's in the package

1. List the kinds of packaging making up the container.
2. What is the weight of each component of the packaging material?
3. What is the energy used for each component?
4. What is the total of the energy used to make the components of the package?

Energy used to manufacture packaging materials

Material	Kilocalories/g	Kilocalories/oz
Paper, cardboard	6 kcal/g	168 kcal/oz
Steel, bimetal	12 kcal/g	336 kcal/oz
Aluminum	64 kcal/g	1,792 kcal/oz
Glass	7.5 kcal/g	210 kcal/oz
Plastic	3.5 kcal/g	98 kcal/oz

Calorie (spelled with a capital C) equals one food Calorie and is equal to one thousand calories (used in physics) or one kilocalorie.

C. Understanding the difference

1. What is the total kilocalorie content of the item (food kilocalories and kilocalorie content of the package)?
2. What is the fraction representing $\frac{\text{food kilocalories}}{\text{total kilocalories}}$?
3. What is the percent of total energy in the item that is food energy?

Adapted from Energy and Order, Mark Terry and Paul Witt, Friends of the Earth Foundation, San Francisco, CA, 1976.

Waste Not - Want Not
by Sarah Ziegler

Our project came as a result of the severe energy shortage in January and February of 1976 and our realization in the Home Economics field, that we could and should play a part in doing "something about it".

The pre-tests showed that the students had some vague ideas that they themselves could play a part in conserving our resources at home and at school; but we felt that there were more areas to explore. Some of the commercial media we received helped increase awareness; but the writing of letters of inquiry to industries and government agencies who are specifically interested in conservation in the home gave us more pertinent information.

With this information the students decided to spread these learnings to the rest of the student body by making colorful posters to display in strategic places about the school building. This fall we will take them to our shopping center to increase the exposure. To reinforce these conservation ideas they evolved a project they called "Vital Facts for the Day". They made an appointment with our new principal and secured his enthusiastic support for making morning announcements twice weekly on the "intercom" of "Vital Facts" that students their age could use to save our resources. 800 students hear this.

The core students (16 in the group) wondered what could be done about the large amount of food thrown away each day at lunch because there is a law that says to receive government subsidy the entire lunch platter must be served, whether the student wants it or not. They then discard what they dislike. The core students planned an unwanted food "recycling" center at the exit of the lunch line where other students who did not want everything they had bought on their tray could give that food to the center. Then any person in the cafeteria could come up to the recycling center and take the food--free. At first the students were skeptical and shy, but after a week of operation more food moved thru the center. By the last day of school, because of support from our principal, the faculty, and the core students, we had an average of 40-50 food items per day given and taken through our center.

Student interest is such that next school year we will be getting volunteers to man the project, at the very beginning of the year. We hope to find new areas of waste and do "something about it". The Assistant Principal has an idea about making "Waste Not" more accurate by instructing the custodians to weigh the trash bags each lunch period (I think they have contests in mind) and making a large bulletin board display across from the cafeteria. The Principal plans to have a BIG ceremony and present certificates to the workers at the food recycling center and cafeteria workers to kick off a new "Waste Not-Want Not" campaign!

Project POWER
by Bob Malkovsky

Project POWER (Positive Options on Waste and Energy Recycling) had a two-fold function and was designed for Ridley Senior High School's Learning Enrichment Program (LEP), which is comprised of academically talented students. Project POWER was run from September, 1978 to the beginning of March, 1979 during three continuous LEP workshops (periods 9 and 10, Monday, Tuesday, Thursday, Friday each week). The group was divided into 2 distinct sub-groups, although some students participated in both.

Prompted by a film produced by Exxon and a slide presentation from Coca-Cola, a discussion was then held to let students decide upon a course of action and divide themselves according to talents and fields of interest. Two areas immediately emerged: PREVENTION and UTILIZATION of food wastes.

The first, known as the Nutrition Group, designed a program to evaluate and prevent food waste in the cafeteria and community. They began by qualitatively and quantitatively evaluating the waste food output of our cafeteria through a garbage can analysis on several days and projecting it over an entire year. The food wastes were analyzed chemically by using two water pollution test kits and later by use of a "Chemanal-System" from the Sargent-Welch Company.

This Nutrition Group then developed a student awareness campaign aimed at preventing waste in the cafeteria. It used posters and closed circuit TV to communicate their message: "WASTE AFFECTS US ALL". The posted material and short TV editorials, shown over the morning announcements several days each week, pointed out how wasting food also wasted gasoline, oil, water, fertilizer and other natural resources valuable to us. They pointed out numerically what was lost in growing, harvesting, transporting, processing, storing, preparing, and disposing of each pound of wasted food, and how much each of us contributed to this.

The Nutrition Group also took home prepared forms from Coca-Cola to evaluate how much food was wasted at home. This prompted the development of the Project POWER cookbook for the community. It was a cooking guide designed to individualize each recipe into separate servings, while also listing each recipe in English and metric units. It also contained a guide of the nutrient values (in calories) of different kinds of foods and those needed for a balanced diet.

The second group, known as the Algae Group dealt with how to utilize the inevitable waste generated by our cafeteria. They began a scientific research project using the waste food as a nutrient fertilizer for growing edible algae. Extensive research began on different types of algae suitable for our needs. Emphasis was placed on edible types, characteristics, ability to harvest, and availability. Four types emerged: Chlorella, Chlamodomonas (+) and (-) strains, and Spirogyra. They were then ordered by students from the Carolina Supply Company.

The disciplines and procedures for scientific methodology were then gone

over in order to set up the process for this laboratory exercise. Problems with control groups, counting, chemical analyses and uncontrolled variables had to be overcome in order to evaluate the two variables being measured: 1) which type of algae utilized the greatest quantity of nutrients per unit of volume, and 2) which type of algae produced the maximum harvestable yield per unit of volume. It was pointed out that one (1) did not necessarily affect two (2), and in the end it was shown that this was true. Chlamodomonas (+) satisfaied the first variable, perhaps due to its motility, while Spirogyra satisfied the second variable when all data were evaluated.

I was very pleased with the attitudes, resourcefulness, and diligence shown by these students. Almost all phases of this function were planned by the students, making my job one of direction. Some phases were unsuccessful, but were just as important in the learning process - such as writing a computer program to store and analyze research data and using different wavelengths (colors) of light to grow different kinds of algae. I felt, however, it was necessary to let students try these in order to see their weaknesses. I also forced students to produce their own methods for doing things, such as counting algae volumetrically before introducing the hemocytometer. This permitted them to see the similarity of methods and more fully understand them.

I feel, overall, it has been a most successful and personally rewarding year.

ELECTRICITY

About 30 percent of our national energy budget is devoted to the generation of electricity. About 30 percent of that energy ultimately is used in our homes, businesses, and factories. The other 70 percent is lost through inefficiencies in the generation and supply system. As we try to reduce our dependence on oil and natural gas, we may be turning more and more to electricity generated by other fuels. Clearly our use of electricity should be a major concern. The activities in this chapter will help the student understand some of the basics of electricity use and will ask each individual to closely review his own value system.

TEACHING NOTES:

Conserving Consumption

This is basically a three-part activity. Each student is first asked to list all electrical appliances in her home, and to categorize them as necessities, conveniences, or luxuries. At this point, it is each student's responsibility to provide her own definition of necessity, convenience, and luxury. When most of the appliances seem to have been remembered and the background conversations rise, it's time to shift.

Organize the kids into groups of half a dozen or so and ask them to share their lists to find out what had been forgotten. Remind them of irons, and vacuum cleaners, and toys, and Christmas lights. Now challenge each group to come to some sort of consensus as to just which electrical appliances are really necessities, which are conveniences, and which are luxuries.

Finally, and most importantly, ask each group to write a definition of necessity. The definition should relate specifically to the use of electricity. The first suggestion is usually something like "only those things we <u>really</u> need". If there is anything at all on such a necessity list, how did the pioneers ever survive? The teacher's job at this point is to float from group to group asking questions which will help each group to clarify its definition. Does lifestyle make any difference? Does ones occupation require certain appliances? Does location or type of residence force any decisions about use of electricty? Do particular climates require electric heaters, or air conditioners, or dehumidifiers, or humidifiers? Are their alternative power sources for any particular appliance or job? Are these alternatives more or less efficient, more or less costly? Are there medical reasons which necessitate use of electricity?

The purposes of this activity are to generate an awareness of the vast number of electrical appliances the typical home utilizes, and to help each student develop her own understanding of how values affect decisions to use or not to use any particular appliance. The teacher should function to help refine this understanding, and should guard against the imposition of any particular value scheme.

Rationai Rationing

Here we take the former activity a step toward quantification. Each student is asked to develop a weekly electricity budget for his own household. After listing each appliance to be used, its wattage, and its weekly hours of use, the kilowatt-hours of electricity consumption can be easily calculated (kwh=watts x hours ÷ 1,000). Allow the students to get their hot water and space heat from outside this base budget.

Now ask each student if he is above or below the national household average of about 130 kwh/wk electricity consumption. What would be given up to get down to the national average, or to reach 90 kwh/wk, or to consume only 60 kwh/wk?

Watt Watching

Now we are ready to investigate the real-world situation of electricity use. Each student is asked to monitor the actual consumption of electricity in her own household and to simultaneously estimate the electric energy being consumed. The time period can be as short as an hour, but should not, for logistic reasons, be longer than a day or two. The first step is to record the starting time of the test period along with the initial electric meter reading. During the test period records should be made of each appliance used and the length of time of its use. Particular attention must be given to automated appliances such as refrigerators, freezers, hot water heaters, and electric space heaters. As in the preceding activity kwh consumed can be calculated as kwh = watts x time ÷ 1,000. At the end of the testing period, record the time and new meter reading. Elapsed time should be calculated by substracting starting time from ending time. Actual electricity consumed will be the first meter reading substracted from the second. Estimated electricity consumed will be the total of the individual appliance usages. How closely do the estimated use and actual use compare? Can the estimate be refined to more closely correspond to the actual consumption? If you are not familiar with the reading of electric meters, here is an example.

The correct reading for this setting would be 81593 kwh. Note that each dial revolves in the opposite direction of its neighbors. Note also that the indicator needle must pass the number before that number is recorded. When in doubt look to the dial to the right. If that dial has passed "0", then the dial to its left has just passed a number. If the dial to the right is approaching "0", then the dial to its left is also approaching its next number.

If the present cost/kwh of electricity is known the cost of electricity consumed can also be calculated (cost/kwh x kwh consumed= cost of electricity).

Appliance Wattage Data Sheet

Use this information sheet as a data base for the previous three activities.

Better yet, have each student develop his own data sheet based on the real consumption of his own real appliances. Every electrical appliance should have a small information plate or sticker somewhere on its bottom or back. This plate will provide information regarding the rated voltage, amperage, and wattage of the appliance. The wattage is our immediate concern. If the wattage is not listed it can be calculated by knowing that volts x amps = watts (v x a = w).

Dim-It

One area of potential electricity conservation is the reduction of excessive and wasteful lighting. This data sheet will provide an information base for comparison to the actual lighting levels found in school or at home. It can be used to help decide where lower wattage bulbs could be substituted.

The most efficient tool to use for making your own light level readings would be a light meter calibrated in footcandles. Typically these meters are fairly sensitive at the lower levels of light intensity. Photography light meters can be used, however they often are not very sensitve to low light levels and usually are not calibrated in footcandles. A conversion chart is provided on the data sheet.

If light intensity should not be reduced for safety or other reasons, another potential for energy savings can be considered. Fluorescent bulbs produce much more light, watt for watt, than do incandescent bulbs (fluorescent bulbs are typically linear or circular tubes, while incandescent bulbs typically are bulbous, have a thin metal filament, and screw into a socket). Fluorescent bulbs require a surge of power to start, but after 15 minutes, or so, of continuous use, their energy savings have balanced out the starting surge. In situations of short intermittent use, like a closet, the incandescent bulb is still the energy saver.

Use the data sheet and your light meter to survey your lighting needs and potential for savings.

Clocks Count

Some types of large scale data can be estimated by using classroom poll or census techniques. Here we attempt to estimate how much money the United States spends to run electric clocks each year. The most basic question is "How many clocks does each American have?" Involve the class in a discussion of clocks per person and try to determine a number. Most clocks are shared clocks, but all must be counted. Don't forget bedroom clocks, clocks on stoves and radios, clocks in school rooms, offices, stores, etc. Not every group will arrive at the same decision but the most common figures we've been getting are 3 clocks per person, 660,000,000 clocks in the U.S., 2 watts per clock, 17.5 kwh/yr/clock, 7¢/kwh, $810,000,000.00/yr in the U.S. just to run electric clocks.

Have fun watching the gaping faces as you calculate Line 10.

Wasting Away

The efficiency with which an electric water heater actually converts electric energy to heat energy can be easily determined. The step-by-step procedure given here is relatively straight forward. In Step 3, the water should not be allowed to boil, if it does, start the experiment over with a cool pot and use a shorter heating time. This will necessitate a slight change in the calculation used in Step 5.

It might be interesting to compare efficiencies of several different brands of coffee pots, to compare integral coffee pots to stove top pots, or to compare the efficiencies of immersion heaters.

In Hot Water

The old shower/bath debate can now be cleaned up. Each student will collect some basic information on her own shower and bath preferences, particularly regarding volume of water used and temperature desired.

As with the previous activity, the calculation steps are fairly well defined.

Project Impact

Outlined here are the year-long activities of a group of fifty-five fifth grade students working under Sandra Bahorik at Upper Perkiomen Middle School in East Greenville, Pennsylvania. They established an E3 Resources Center, studied school and nome energy consumption, developed personal energy conservation strategies, staged an energy debate, and published a newsletter. Their learnings and activities had an impact far beyond themselves.

Conserving Consumption

Directions:

List all electric appliances you have at home. Include them all, even those you do not use. As you list them, rank each as necessity, convenience, or luxury. The ranking should be your own decision based upon your personal definitions of necessity, convenience, and luxury.

Necessity	Convenience	Luxury

Once you've completed your list and made your ranking decisions, you should join your group to compare lists. Can the group agree on what items are necessities? Can the group define "necessity" in the context of today's use of electricity?

ne·ces·si·ty/ni-'ses-ət-ē, _____

Rational Rationing

As the cost of energy continues to rise, many people are trying to find ways to cut back their consumption. If your household use of electricity were rationed, how would you use your allotment? We'll assume that your hot water and space heating needs are covered outside of your ration. You need only consider the electricity you use to run your appliances. First list the appliances you intend to use. Then list the wattage rating of each; check the "Appliance Wattage Data Sheet" or the information plate attached to the appliance. Next estimate the hours per week you will use that appliance. You are now ready to calculate the energy consumed per week by multiplying each wattage by the corresponding number of hours of use. This figure will be in watt-hours (wh.). Electricity is sold by the kilowatt-hour (kwh) which is 1,000 watt-hours; so divide your watt-hour figure by 1,000. Add the figures of the final column to show your total weekly consumption.

Appliance	Wattage (w)	Weekly Hours of Use (h)	Consumption in kwh (kwh = $\frac{w \times h}{1{,}000}$)

TOTAL-- _____

Have you included all of the appliances you intend to use? Don't forget the kitchen, the workshop, toys, lights, etc. A typical U.S. household consumption rate is about 130 kwh/wk. Are you above or below that mark? What would you discard or cut back if your ration was 90 kwh/wk? How would you allot 60 kwh/wk.?

Watt Watching

Name_____

Time period of estimate:

from_____
to _____
elapsed time_____hrs

meter reading (pre)_____kwh
meter reading (post)_____kwh
actual energy consumed_____kwh
(post-reading minus pre-reading)

Current cost/kwh of electricity (c)_____

Appliance	Wattage (w)	Time Used (t, in hours)	Electricity Used ($\frac{w \times t}{1,000} = E$, in kwh)

Total estimated energy consumed:_____kwh

Total cost of electricity used:

c x actual energy consumed = _____
c x estimated energy consumed = _____

Appliance Wattage Data Sheet

The chart below tabulates the average wattages of a number of common household appliances. Since the watt (W) is a measure of power (745.7 watts = 1 horsepower), knowing the length of time that a certain level of power is applied allows us to calculate the energy consumed. This is typically measured in kilowatt hours (kwh), that being 1,000 watts used for 1 hour, or 1 watt used for 1,000 hours, or 100 watts used for 10 hours, etc. This table can be used to estimate your own energy consumption in kwh by multiplying the wattage listed by the number of hours you use the appliance and dividing by 1,000. For most appliances the hours of use will be precisely the length of time you have them turned on. Refrigerators and freezers, however, will turn themselves on and off depending on how warm the surrounding air is, how efficient the appliance is, and how long you keep the door open. You could sit beside it for a day and record the cumulative time the compressor was on or you can assume an estimated 10 hours/day. To calculate your dollar cost, multiply your kwh figure by your current $/kwh cost for electricity (check your latest bill). As these are national average wattages, your specific appliances may vary considerably. You can localize these figures by checking each of your own appliances. Somewhere on the bottom or back of each appliance there should be a small plate or sticker with certain electrical information, particularly regarding volts (V), amps (A), and watts (W). If all three figures are not listed, two will be and the third can be computed by knowing that V X A = W.

AVERAGE WATTAGES OF HOUSEHOLD APPLIANCES*

Food Preparation		Food Preservation		Home Entertainment	
Blender	390	Freezer (15 cu ft)	340	Radio	70
Broiler	1400	Freezer (frostless 15)	490	Radio/Record Player	110
Carving Knife	92	Refrigerator (12 cu ft)	240	TV (b/w, tube)	160
Coffee Maker	890	Refrigerator (frostless 12)	320	TV (b/w, solid state)	55
Deep Fryer	1400	Ref./Freezer (14 cu ft)	330	TV (color, tube)	300
Dishwasher	1200	Ref./Freezer (frostless 14)	620	TV (color, solid state)	200
Egg Cooker	520				
Frying Pan	1200	**Housewares**		**Laundry**	
Hot Plate	1300				
Microwave Oven	1500	Clock	2	Clothes dryer	4900
Mixer	130	Floor Polisher	310	Iron (hand)	1000
Range with Oven	12000	Sewing Machine	75	Washing Machine (auto)	510
Roaster	1300	Vacuum Cleaner	630	Washing Machine (manual)	290
Sandwich Grill	1200			Water Heater (standard)	2500
Toaster	1100	**Comfort Conditioning**		Water Heater (quick rec.)	4500
Trash Compactor	400				
Waffle Iron	1100	Air Cleaner	50	**Health and Beauty**	
Waste Disposer	450	Air Conditioner (room)	1600		
		Bed Covering	180	Hair Dryer	380
		Dehumidifier	260	Heat Lamp (infrared)	250
		Fan (attic)	370	Shaver	14
		Fan (circulating)	88	Sun Lamp	280
		Fan (rollaway)	170	Toothbrush	7
		Heater (portable)	1300	Vibrator	40
		Heating Pad	65		
		Humidifier	180		

*Data adapted from information from the Electric Energy Association

Dim It

Is there enough light for you to safely and efficiently perform your tasks; or are you wasting energy by using more light than you need? To find out, measure the light intensity, in footcandles, with a light meter. Compare your findings with the recommendations listed below.

TASK	RECOMMENDED LIGHT LEVEL* (in footcandles)
Reading and Writing	
books, magazines, newspapers	30
handwriting and indistinct print	70
critical seeing tasks	100
drafting	200
Office Areas	
bookkeeping, business machine operation	100
computer operation	100
filing, mail sorting	50
conferring, interviewing	30
General	
any area involving a visual task	30
washrooms	30
safety on stairways, corridors	10
areas for relaxation, conversation	10
playing cards, billiards	30
table tennis	20
Kitchen, Laundry, Grooming	
sink	70
counter space	50
laundering, ironing	50
grooming	50
Sewing and Handicrafts	
occasional sewing	50
prolonged sewing	100
close craftwork, reading diagrams, fine finishing	100
measuring, sawing, assembling	50
Industrial (condensed list)	
rough-easy seeing	30
rough-ordinary seeing	50
medium	100
fine	500

If you don't have a light meter that reads directly in footcandles, you can use a photographer's light meter or a camera with a built-in meter.

First set the film speed of the light meter at ASA 100. Then set the shutter speed at 1/60 sec. Find the appropriate f-stop, and read the corresponding number of footcandles from the chart below.

Sources:

"Planning Your Home Lighting", Home and Garden Bulletin No. 138, U.S. Department of Agriculture.

Standard Practice A 11.1 - 1973 of the American Standards Institute, which is also The Illuminating Engineering Society's Recommended Practice for Office Lighting.

Clocks Count

Just how much do Americans spend to run electric clocks in a year? To answer that question you will need several bits of information. Some of that information you will have easily at hand. Some of it you may have to estimate. Your estimates will be more accurate if you work with a group and try to arrive at a group consensus of opinion.

_____1. On the average how many plug-in clocks are there per person? Don't forget bedroom clocks, clocks on stoves and radios, clocks in school rooms, offices, stores, etc. Remember also that most clocks are shared. If there are 30 people in a room with one clock, that gives each person 1/30 of a clock.

_____2. How many people are there in the United States?

_____3. What is the total number of clocks in the U.S.? Multiply #1 by #2.

_____4. What is an average wattage for a clock? Poll your group, or check some clocks, or find a wattage chart.

_____5. How many hours are there in a year?

_____6. How many watt-hours does one clock use in a year? Multiply #4 by #5.

_____7. How many kilowatt-hours does one clock use in a year? Divide #6 by 1,000.

_____8. In the entire U.S., how many kilowatt-hours of electricity are consumed each year by clocks? Multiply #3 by #7.

_____9. How much does electricity cost per kilowatt-hour? Check a recent electric bill.

_____10. How much do we spend on clocks? Multiply #8 by #9.

Wasting Away

There are many appliances on the market today designed to perform the same functions. Some can do their jobs more efficiently than others. Here is a simple procedure which will allow you to check the efficiency of a coffee pot.

_____1. Check the wattage rating of the coffee pot. It should be stamped on a label on the underside of the pot. If only voltage and amperage are listed, multiply them to yield wattage.

_____2. Pour 1 pint of water into the coffee pot. Measure the temperature in °F.

_____3. Turn the pot on. Allow it to heat for 10 minutes. Turn it off and measure the temperature again in °F.

_____4. Calculate the energy transferred to the water in BTU. With 1 pint of water, the energy (in BTU) equals the change in temperature (in °F), so substract #2 from #3.

_____5. Calculate the electricity consumed in watt-hours. Multiply the wattage rating of the pot by the number of minutes it was turned on and divide by 60 to get watt-hours consumed (#1 x 10 ÷ 60).

_____6. Calculate the energy consumed in BTU. 1 watt-hour equals 3.4 BTU, so multiply #5 by 3.4.

_____7. Calculate a ratio of efficiency. Divide #4 by #6.

In Hot Water

You've probably heard people argue that taking a shower saves energy compared to taking a bath. This assumes that you use less water. With this experiment we'll not only find out how much water you use, but also how much energy it takes to heat that water.

Bath	Shower		
____ gal.	____ gal.	1.	We first need to know how much water you use. Fill the tub to your normal bath level and bail the water out keeping track of the amount of water removed. For the shower, simply take your normal length shower but leave the drain closed. Once you've finished the shower, bail out the water and measure it just as you did for the bath. Record your measurements in gallons. If you wait until you actually need a bath or shower, you won't be wasting water just for your measurements. While you are bathing, we also need some temperature information.
____ °F	____ °F	2.	Record here the temperatures of your bath water and your shower water, in degrees Fahrenheit.
____ °F	____ °F	3.	Next we need to know the temperature of the cold water entering your house. This is most easily measured by letting the cold water run for three minutes, or so, and then taking a temperature reading of the water before the room temperature has a chance to warm it. This reading should be the same for both bath and shower. Take this reading in degrees Fahrenheit also.
____ °F	____ °F	4.	What are the differences between your hot water temperatures and the cold water temperature? (substract #3 from #2).
____ BTU/ gal.	____ BTU/ gal.	5.	Now multiply #4 by 8.33 (BTU capacity of water per gallon per degree Fahrenheit) to calculate the energy needed to heat one gallon of water to your bathing temperatures.

Bath	Shower	
_____ BTU	_____ BTU	6. Calculate the energy needed for your whole bath or shower by multiplying #5 by #1.

Questions:

How much energy would a quick shower take?

Would you save much by using cooler water?

How much does electricity cost in your area?

If each KWH is the equivalent of about 3,000 BTU, how many KWH does your bathing take?

How much does one bath or shower cost?

Project Impact
by Sandra Bahorik

"Project Impact" was primarily concerned with disseminating basic knowledge of energy, economics, and the environment (and their interrelationships) to fifty-five fifth grade students who would, in turn, disseminate their knowledge to other Middle School students and the community. As a result of acquiring some basic knowledge of E3, it was hoped those involved would also develop a local concern for the need to conserve energy.

Many methods were used to achieve effective awareness of E3 concerns and their interrelationships. Students established an E3 Resource Center in which student research was conducted; viewed films, filmstrips and video-tapes; completed various empirical activities both in the classroom and outside; used text books; took numerous field trips, including businesses within our community; invited and listened to guest speakers from the community; kept daily logs of activities; and studied school and home energy consumption resulting in development and practice of personal conservation strategies.

Community and school awareness of E3 interrelationships was also of importance of "Project Impact". This was achieved via public meetings, hallway displays, local newspaper coverage, the "Project Impact" Resource Room open to both the community and the Middle School; a debate between 5th and 7th grade students (video-taped for other classes to use); an open door policy to visit our class (many students and parents did); a school-wide "SunDay" contest; and "The Energy Express".

The main focus of Project Impact's community and school awareness drive was the newsletter "The Energy Express". Written and edited by children, its goal was to help others learn what the children had already learned. Three issues were printed and sent home with Middle School students. A true highlight of the year was a letter received from the U.S. Department of Energy concerning the newsletter stating:

> "The energy awareness of the students involved in this project is gratifying. One of the greatest challenges confronting the Administration is to raise the energy consciousness of Americans. Creative efforts such as "The Energy Express" have incalculable ramifying effects."

Throughout the entire project the students' enthusiasm never waned. The project was action-oriented, thus keeping their attention and allowing the students to use their emerging peer values in cooperative group work that encouraged self direction and independence in learning. The subject

Project Impact (cont'd)

matter was directed toward a tangible goal (such as saving fuel, saving money, teaching others, writing articles). In this way the body of knowledge was worth learning because it was relative to the students' lives, the students' community. This point is a significant one, because as a result the students were eager to learn and eager to discuss and, at times, debate what they learned. The result was, of course, true learning as evidenced by test results, parent comments, overt behavior, and, hopefully, long term acquisition of knowledge.

SPACE HEATING

Between 50 and 60 percent of a household's energy budget is devoted to space heating. Maintaining efficient housing can result in significant energy savings, both for the fuel consumer and the nation at large. The majority of this chapter is an in-depth home heat audit, while the other activities can serve supportive roles to the audit.

TEACHING NOTES:

Draft-O-Meter

This is a simply made tool which can be used as a qualitative measure of infiltration or drafts in a building.

Thermostat Stats

Don't let the degree day's ease of calculation obscure its paramount importance to heat-load analyses. In the home heat audit which follows, the yearly accumulation of degree days is used extensively in the heat-loss calculations. You could, if you wished, expand this one week activity to encompass the whole heating season. It might be interesting to compare your own data with that provided in the Yearly Degree Days Chart.

R Values Important?

Provided here is a technique which can be used to experimentally determine the R value, or resistance to heat flow, of a wall, ceiling, door, or any other barrier between the indoors and the outdoors.

The R value can be thought of as the number of square feet of surface needed to transfer one BTU of energy during one hour when the difference in temperature across that barrier is one degree Fahrenheit. If you want to keep heat in, the higher the R value is, the better the insulation is. Mathematically the R value is in units of $ft^2/hr/^oF/BTU$. A closely allied concept is the U value, a measure of the ability of a barrier to conduct heat. It is the mathematical inverse of the R value or $BTU/ft^2/hr/^oF$.

To determine the R value with this technique you must take three temperature measurements: inside surface, outside surface, and inside ambient. The surface readings should be made with a thermometer specifically designed for surface measurement. The inside ambient reading can be made with an ordinary thermometer held in the air at the same height as the surface readings.

Once these readings have been taken, you'll need to calculate the difference between the inside surface temperature and the outside surface temperature as well as the difference between the inside ambient (air) temperature and the inside surface temperature. The temperature difference between inside and outside surface must be at least 10^oF before this technique becomes useful. To read the R Value Determination Chart first find the arc corresponding

to your inside/outside surface difference. Follow this arc until it intersects the vertical line representing your inside ambient/inside surface difference. From that intersection point run a horizontal line to the left until it intersects the R value scale. Read your R value from this final intersection.

The prime advantage of this technique is that you do not need to know how the wall or barrier was constructed or what types of insulation were included. Its main disadvantages are the need for special thermometers and for cold weather.

Home Heating Audit

The next 14 items, from the "Home Heat Loss Data Survey" through the "Heat Loss Summary Worksheet",comprise the complete audit package. Four of these items provide basic information for use with the computations required in the worksheets. After the initial "Data Survey" has been completed, each of the seven worksheets can be utilized independently of the rest. The two summary sheets are based on data provided by the calculations in the worksheets. If you don't have the time to run the complete audit with your students consider doing just one or two of the "Conductant Heat Loss Worksheets". You could even use the "Conductant Heat Loss Worksheet: Windows and Doors" to analyze one single window. This whole packet has been organized with two main factors in mind: student gains in understanding, and flexibility of application.

Home Heat Loss Data Survey

With this survey form you should be able to collect the information you need to perform the calculations for the remainder of this audit. A partial audit can be performed on partial data, but the audit will be most useful if complete information is secured. This form could be filled out directly by the participating homeowner, then given to the students for analysis. It could also be used by the students themselves as they work on-site to collect the necessary information.

Conductant Heat Loss Calculations

There are two major modes of heat loss from homes: conduction and convection. Conductant heat loss occurs as heat flows through solid materials such as wood or window glass. Convectant losses, on the other hand, occur as warm inside air flows through cracks and openings in a building and is replaced by cold outside air. The formulae on this page are to be used on conductant losses.

Conductant heat loss is dependent on four major factors: the thermal resistance of your barrier (wall, ceiling, etc.), the amount of surface area exposed to the cold, the difference between the inside and outside temperatures, and the length of time under those conditions. The formulae offered here will allow you to calculate heat loss on an hourly, daily, or heating season basis. All of the worksheets which follow use the formula for total heating season losses. With

only minor changes you could substitute an hourly or daily formula.

Degree days and R values were discussed in the "Thermostat Stats" and "R Values Important?" activities. BTU's, however, have not been fully explained. Basically, the BTU, British Thermal Unit, is a measure of energy. Its metric equivalent is the calory. While a calory is the amount of energy needed to raise the temperature of one gram of water one degree Celsius, a BTU is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit. One BTU is about equal to 250 calories. Four BTU's are about equal to one kilocalory (the food Calories that diet books count). The energy contained in one wooden kitchen match is about equal to one BTU. All of the formulae on this data sheet are designed to calculate BTU's of energy lost.

Yearly Degree Days

Use this chart to estimate your own local heating season heat load. Find one of the major cities nearest you and use its yearly degree day figure as your own. If you live somewhere between two of these cities you may estimate your own degree days by using the average of the neighboring cities. A still better approach would be to call your local weather station or heating contractor for actual local data.

Insulation Value of Common Materials

Listed here you will find representative building materials and their respective R values. The R value of any particular barrier will be the sum of the R values of its composite materials. As you calculate R values in the following worksheets keep in mind that most of the R values listed here refer to some specific thickness of material. If your particular material is thinner or thicker you should adjust the R value accordingly. Note that if an air space is 3/4 of an inch or more, the R value does not change. In such cases, the extra thickness is offset by increased air movement. One interesting factor is called "surface resistance". This resistance to heat flow will vary depending on the speed of air movement across the surface. Therefore, the "exterior surface resistance" value is less than the "interior surface resistance" value. Don't forget to include these values in your calculations. If you can't find your particular material listed, estimate its value by comparison to a similar material that is on the list.

Conductant Heat Loss Worksheet: Ceiling

This begins a series of seven worksheets, each of which analyzes a different facet of heat loss from a building. Each worksheet can be used independently of the rest or all the worksheets can be summarized using the "Heat Loss Summary".

We start with ceilings because they are relatively easy. Typically a house's ceiling is of uniform construction, which means a single calculation can be made. If there are a variety of ceilings in one house, then for the greatest accuracy, multiple calculations should be made. For our purposes, we'll consider the "ceiling" to be everything above

the heated portion of the house and below the sky. Often this will include a ceiling, attic, and roof. When it is impossible to tell exactly what construction was used, your best judgement will have to do. If you live in an apartment below another heated apartment, you can skip the ceiling conduction calculations.

Conductant Heat Loss Worksheet: Floor

The floor we are concerned with is the floor of the lowest heated portion of your house. When standing in an unheated basement, the floor of interest is above you; if the basement is heated, the important floor is below you.

Because the soil below the frost line is often warmer than the surrounding winter air, some floors will not experience the same heat load as will exposed walls or ceilings. To accommodate this a "Floor Exposure Factor" must be included in your calculations.

If you live in an apartment above another heated apartment, you can skip the floor conduction calculations.

Conductant Heat Loss Worksheet: Windows and Doors

Here you will need information from each window and door regarding its size and R value. With respect to window R value, the most important consideration is the number of panes of glass between the inside and the outside. A "thermopane" window counts as double pane just as a storm window provides a second pane of insulation. If your windows are of uniform size, you won't have to calculate each independently but can count the number of windows of a particular size and multiply. Doors are calculated similarly, that is, a storm door will add extra insulation for any particular entry.

Conductant Heat Loss Worksheet: Walls

The R value calculation for walls is the sum of the R values of the materials that compose the walls. If you are not sure of the wall construction, remove several socket and switch coverplates to get an interior view.

The wall area is calculated by first computing the gross wall area (height of walls x perimeter of building) and then subtracting the window and door area. If you live in an apartment or townhouse that shares a wall with another heated area you won't have to include that wall in your calculations.

Convectant Heat Loss Data Sheet: Windows and Doors

Convectant heat losses occur as warm inside air is exchanged with cold outside air. The volume of these drafts will be dependent on the speed of the outside wind and the size and length of the cracks through which the air escapes. The chart on this data sheet will tell you the amount of air (in cubic feet) you are losing each hour for each foot of crack. You will need to know how well fitted your windows are and how fast the outside air is blowing. If you don't have real wind speed

data, use the 10 mph column as an estimate for house sites of normal exposure. The heat lost with these air drafts will be dependent not only on the volume of air lost, but also on the temperature difference between the inside and the outside air, and on the heat capacity of air. The necessary formulae are included in the data sheet.

Convectant Heat Loss Worksheet: Windows and Doors

Use this sheet for the actual calculation of heat lost through drafts around windows and doors. You will need to know the total crack length of windows and doors of the various type and fit categories of the previous chart. Crack length of any individual window or door can easily be estimated by measuring its perimeter. If you have double-hung windows with no storm window, you should add to the perimeter measure the length of the additional central crack (another width measure). Use the table and formulae provided to calculate the heat lost.

Convectant Heat Loss Worksheet: Foundation

Actual measurement of the cracks occurring in a building's foundation would be difficult and time consuming. Therefore a chart is provided to estimate the volume of air lost. Find the type and condition of your foundation on the left side of the chart and read the air changes per hour from the right hand column. These changes per hour will be relative to the overall volume of the heated portion of your house so you will need to know its length, width, and height. The calculations which follow will bring in to account the heat capacity of air and the degree days of heat load to give you the BTU's of heat lost in one heating season.

Convectant Heat Loss Worksheet: Walls

A building's wall cracks would be at least as difficult to measure as those in the foundation. Therefore a similar estimation and calculation technique is provided here.

Infiltrative Air Exchange Summary

At this point we begin to summarize our findings from the previous worksheets. Here we are concerned with the previous three worksheets dealing with air convection.

It would not be desirable to leave your doors and windows open all winter, neither would it be good to completely seal a building from fresh air. You don't want to restrict your oxygen supply nor do you want to hold in unwanted odors (last night's fish fry?). Generally, one complete air exchange per hour is considered adequate for fresh air and ventilation. With this worksheet you can compare your exchange rate with the ideal.

Heat Loss Summary

This single sheet should be the one of most interest to the homeowner. With it you can compare not only the heat lost through each sector, but also the fuel needed and the cost of the fuel. This information can be the basis for making decisions about retrofitting insulation, storm windows, or a new furnace, to name just a few possibilities.

To complete this sheet you will need to know the type of fuel used, the type of furnace or heater used, the current cost of fuel, and the final BTU calculations from the seven preceding worksheets.

As a check of the accuracy of this modeling technique your fuel and cost totals can be compared to the sum of the fuel and cost figures from last year's bills.

ROI (Return On Investment)

Use this technique to determine just how economic a proposed retrofit might be. You will need to calculate the cost of the heat lost under the existing conditions, the cost of the heat lost under the proposed improved conditions, and the cost of the proposed improvements.

The basic process is straightforward and simple, however the accumulation of all the necessary information can be complex and time consuming. It is suggested that individual retrofit options be considered independently, at least until the students have a clear grasp of the general analysis concept.

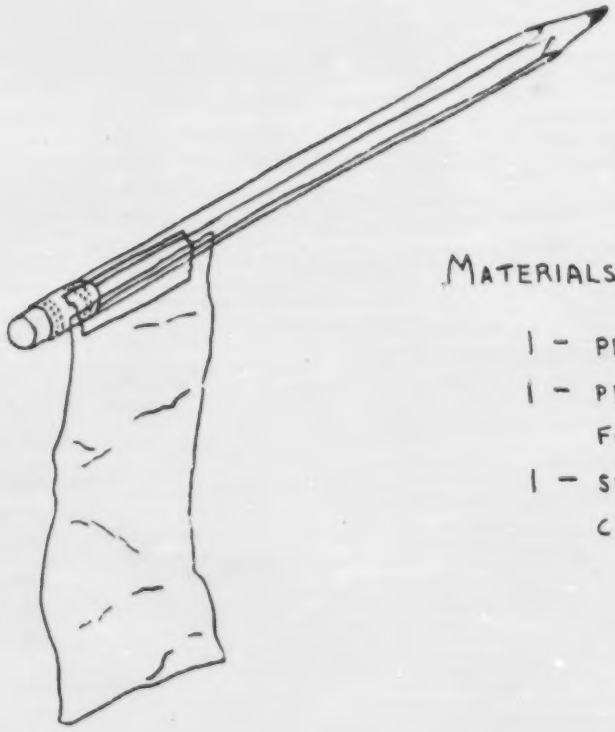
The calculations of heat loss can be performed with the same worksheets used for the preceeding Home Heat Audit. Estimates of retrofit costs, excluding labor, can most easily be made by use of current Sears Catalogs or catalogs of other hardware or materials outlets. Labor can be assumed to be provided by the homeowner or can be estimated by interviewing local contractors.

Project DETECT

Here is the final report of a project run by students and their teacher, Nicholas Ignatuk, at Ridley Senior High School, in Folsom, Pennsylvania. Their primary objective was to offer free home heat audits to their local community. The audit technique used in this book has been adapted from the methods used by the Ridley students.

DRAFT - O - METER

TRY BUILDING THIS SMALL INSTRUMENT, AND USE IT TO FIND THE DRAFTY SPOTS IN YOUR HOUSE.



MATERIALS LIST:

- 1 - PENCIL OR STICK
- 1 - PIECE OF PLASTIC FOOD WRAP, 2" x 6"
- 1 - SHORT PIECE OF CELOPHANE TAPE

CHECK SUSPECTED DRAFTS BY DANGLING THE PLASTIC "FLAG" IN FRONT OF THE DRAFTY SPOTS. WATCH TO SEE HOW HIGH IT FLIES.

DOES THE DRAFT BLOW CONSTANTLY, OR OFF AND ON?

WHERE IS THE STRONGEST DRAFT?

ARE THERE MORE DRAFTS WHEN THE WIND OUTSIDE IS HIGH?

ARE THE DRAFTS STRONGER WHEN THE FIREPLACE IS LIT?

IN THE SUMMER WITH AIR CONDITIONING, ARE THERE STILL DRAFTS?

Thermostat Stats

One of the most basic pieces of heating season data is the degree day. Engineers, builders, and fuel suppliers use it extensively in design, construction, and timing of fuel replenishment. It is a measure of the coldness of a place and as such can be used to determine how much heat a building will lose. By coldness we mean not only how low the temperature gets, but also how long it stays low. One degree day is accumulated for each degree (°F) that the average daily temperature is below 65°F. If the average temperature one particular day is 45°F, then 20 degree days were accumulated that day. Weekly or yearly records can easily be kept simply by adding the individual days. Below we will calculate the number of degree days accumulated in a week. You will need to record the lowest and highest temperatures each day for a week. Next calculate the average temperature for each day by adding the lowest temperature to the highest temperature and dividing by two. Subtract this average from 65°F and you will have the degree days for each day. Add these and you will have the total degree days for one particular week.

Dates: From_____, To_____

Place: _____

Date	Lowest Temperature (L)	Highest Temperature (H)	Average Temperature ($A = \frac{L + H}{2}$)	Degree Days (65°-A)

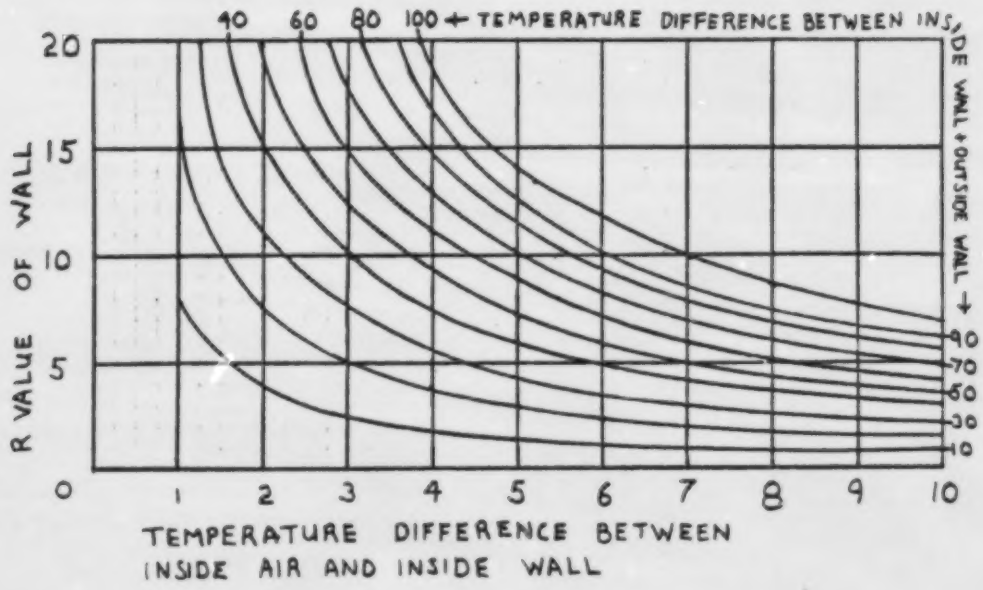
TOTAL--_____

R Values Important?

The R value is the standard unit of measure for the thermal resistence of a barrier, that is, how effectively a wall, or ceiling, or door will resist the flow of heat. The higher R values indicate greater insulation. The lower R values indicate greater heat transfer. With fuel prices continually on the rise, high R values are making more and more sense.

For any particular insulating barrier, its R value can be quickly determined with 3 temperature measurements: inside air temperature, inside wall temperature, and outside wall temperature. The wall temperatures should be taken on the surface and directly opposite each other. The inside air temperature should be taken at the same height and away from any hot or cold objects. All temperatures should be taken in °F. Calculate the difference between the inside wall and outside wall temperatures and the difference between the inside air and the outside wall temperatures. Knowing these differences, use the chart below to determine the R value. If the difference between the inside wall and outside wall temperatures is less than 10 °F, you'll have to find a shadier spot, or wait for a colder day.

R Value Determination



Home Heat Loss Data Survey

Name:_____

Type of House:

Mobile Home	_____
One Story	_____
Two Story	_____
Split Level	_____
Townhouse	_____
Apartment	_____
Other (specify)	_____

House Sits On:

Concrete Slab	_____
Crawl Space	_____
Basement	_____
Posts or Pillars	_____
Other (specify)	_____

Primary Heat System:

Type of Fuel		Amount/Winter (from Fuel Bills)	Cost/Winter (from Fuel Bills)
Fuel Oil	_____	_____gallons	$_____
Natural Gas	_____	_____cubic feet	$_____
Coal	_____	_____tons	$_____
Electric/Baseboard	_____	_____kwh	$_____
Electric/Heat Pump	_____	_____kwh	$_____
Solar	_____	_____kwh (if active system)	$_____
Other_____		_____	$_____

Auxiliary Heating:

Type of Heater	Hours Used/Week
Fireplace	_____
Wood Stove	_____
Electric Space Heater	_____
Solar	_____
Other_____	_____

Thermostat Settings:

Day_____ Night_____

Special Problems:

Please describe any special heating problems or concerns you may know of.

Flooring:

Material	Type	Thickness
Carpet		
Linoleum		
Floor Surface		
Subfloor		
Insulation		
Other		
Other		

Ceiling/Roofing:

Material	Type	Thickness
Shingling		
Sheathing		
Roof Insulation		
Air Space		
Attic Flooring		
Ceiling Insul.		
Vapor Barrier		
Inside Surface		
Other		
Other		

Walls:

Material	Type	Thickness
Outside Surface		
Building Paper		
Plywood		
Air Space		
Insulation		
Vapor Barrier		
Inside Surface		
Other		
Other		

40 Space Heating

WINDOWS/DOORS:

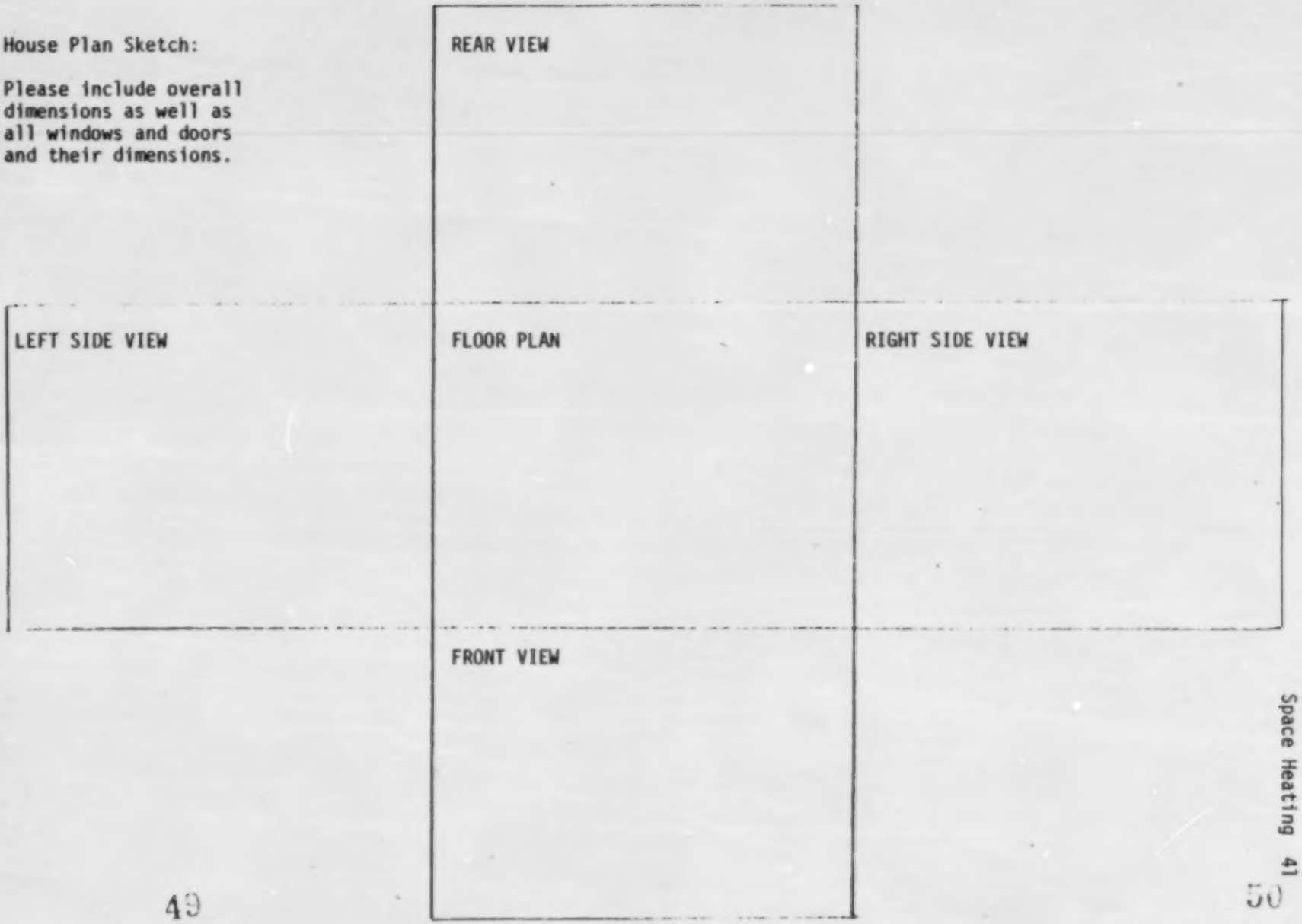
TYPE	HEIGHT	WIDTH	NUMBER SAME SIZE
Single Pane			
Double Pane or Thermopane			
Triple Pane			
Uninsulated Door			
Insulated Door			
Storm Door			

WINDOW FIT DESCRIPTION:

Window Type	Fit Type	Check If Appropriate
Double-Hung Wood Sash	Average Fitted Non-Weatherstripped	
	Average Fitted Weatherstripped	
	Poorly Fitted Non-Weatherstripped	
	Poorly Fitted Weatherstripped	
Double-Hung Metal Sash	Non-Weatherstripped	
	Weatherstripped	
Rolled-Section Steel Sash	Industrial Pivoted	
	Residential Casement	

House Plan Sketch:

Please include overall dimensions as well as all windows and doors and their dimensions.



Conductant Heat Loss Calculations

Home heat loss by conduction is dependent upon several factors: thermal resistance (of walls, ceilings, etc.), outside surface area, inside and outside temperatures, and length of time. These factors can be combined in several simple formulas, depending on the data you have and the results you need.

To calculate heat loss per hour:

$$Qh = \frac{A\ (Tin-Tout)}{R} = \frac{A\ (\Delta T)}{R} = A\ (\Delta T)\ U$$

To calculate heat loss per day:

$$Qd = \frac{24\ A\ (\Delta Ta)}{R} = \frac{24\ A\ (Dd)}{R}$$

To calculate heat loss per heating season:

$$Qs = \frac{24\ A\ (Dt)}{R}$$

Qh = heat loss per hour (BTU/hr)
Qd = heat loss per day (BTU/day)
Qs = heat loss per season (BTU/season)
A = area (sq. ft.)
Tin = temperature inside (° F)
Tout = temperature outside (° F)
Δ T = temperature differential (° F)
Δ Ta = average daily temperature differential (° F)

R = thermal resistance = $\frac{1}{U}$ = sq. ft./hr/°F/BTU

U = thermal conductance = $\frac{1}{R}$ = BTU/sq. ft./hr/° F

Dd = degree days on any specific day
Dt = total degree days for heating season

Yearly Degree Days

Site	Degree Days
AL, Birmingham	2600
AK, Anchorage	10900
Fairbanks	14300
Juneau	9100
AZ, Flagstaff	1800
AR, Little Rock	3200
CA, Los Angeles	2100
San Francisco	3000
CO, Denver	6300
CT, Hartford	6200
DE, Wilmington	4900
FL, Miami Beach	140
Tallahassee	1500
GA, Atlanta	3000
Savannah	1800
ID, Boise	5800
IL, Chicago	6200
Springfield	5400
IN, Indianapolis	5700
IA, Des Moines	6800
KS, Topeka	5200
KY, Lexington	4700
LA, New Oreleans	1400
ME, Portland	7500
MD, Baltimore	4700
MA, Boston	5600
MI, Detroit	6200
Sault Ste. Marie	9000
MN, International Falls	10600
Minneapolis	8400
MS, Jackson	2200
MO, St. Louis	4900
MT, Missoula	8100

Site	Degree Days
NE, Valentine	7400
NV, Las Vegas	2700
NH, Concord	7400
Mt. Washington	13800
NJ, Atlantic City	4800
MN, Albuquerque	4300
NY, Albany	6900
Buffalo	7100
Central Park	4900
NC, Asheville	4000
ND, Fargo	9200
OH, Columbus	5700
OK, Oklahoma City	3700
OR, Eugene	4700
PA, Philadelphia	5100
Pittsburgh	6000
RI, Providence	6000
SC, Charleston	2000
SD, Rapid City	7300
TN, Nashville	3600
TX, Brownsville	600
Dallas	2400
Houston	1400
UT, Salt Lake City	6100
VT, Burlington	8300
VA, Richmond	3900
WA, Seattle	4400
WV, Charleston	4500
WI, Madison	7900
WY, Cheyenne	7300

Degree days are calculated by substracting the average daily temperature from 65°F, assuming that other heat sources (lights, bodies, sun, stove) would provide the heat needed to raise 65°F to 68°F. The use of degree days in thermal load analysis greatly simplifies many calculations. It assumes, however, a house held at a constant 68°F. If you keep your house, or part of your house, at any other temperature, for the whole day or for certain parts of the day, you may wish to do a more refined study. By using the "heat loss per day" or "heat loss per hour" formulas, you can more closely monitor a wider set of variables.

Insulation Value of Common Materials

This list is not intended to include all types of building materials, but only materials commonly used in residences. If necessary, select the material most similar, and the resulting values should not substantially affect the calculation.

MATERIAL	THICKNESS (inches)	R VALUE
Air Film and Spaces:		
Air space, bounded by ordinary materials	3/4 or more	.91
Air space, bounded by aluminum foil	3/4 or more	2.17
Exterior surface resistance	----	.17
Interior surface resistance	----	.68
Masonry:		
Sand and gravel concrete block	8	1.11
	12	1.28
Lightweight concrete block	8	2.00
	12	2.13
Face brick	4	.44
Concrete cast in place	8	.64
Building Materials - General:		
Wood sheathing or subfloor	3/4	1.00
Fiber board insulating sheathing	3/4	2.10
Plywood	5/8	.79
	1/2	.63
	3/8	.47
Bevel-lapped siding	1/2 x 8	.81
	3/4 x 10	1.05
Vertical tongue and groove board	3/4	1.00
Drop siding	3/4	.94
Asbestos board	1/4	.13
3/8" gypsum lath and 3/8" plaster	3/4	.42
Gypsum board (sheet rock)	3/8	.32
Interior plywood panel	1/4	.31
Building paper	----	.06
Vapor barrier	----	.00
Wood shingles	----	.87
Asphalt shingles	----	.44
Linoleum	----	.08
Carpet with fiber pad	----	2.08
Hardwood floor	----	.71
Insulation Materials (mineral wool, glass wool, wood wool):		
Blanket or batts	1	3.70
	3-1/2	11.00
	6	19.00
Loose fill	1	3.33
Rigid insulation board (sheathing)	3/4	2.10
Windows and Doors:		
Single window	----	approx. 1.00
Double window	----	approx. 2.00
Exterior door	----	approx. 2.00

Source: Ashrae via Project Retro Tech

Conductant Heat Loss Worksheet: Ceiling

Ceiling Construction	R Values
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
TOTAL (R)--	_____

Total Area

Length (L) = _____ ft

Width (W) = _____ ft

Total Area (A) = L x W

Total Area (A) = _____ sq. ft.

Heat Loss Calculations

Total degree days per heating season (Dt) = _____

Heat Loss per season (Qs) = $\frac{24 \times A \times Dt}{R}$

Qs = $\frac{24 \times (\quad) \times (\quad)}{(\quad)}$ = _____ BTU

Total conductant heat loss: ceiling = _____ BTU

Conductant Heat Loss Worksheet: Floor

Floor Exposure Factor (Fe)

Building on posts or pillars with no skirts below floor	1.0
Crawl space skirted	.8
Rock wall basement	
More than 2 feet of basement wall exposed above grade	
Building on slab	.5
Building with tight crawl space	
Building with tight basement (heated or unheated)	

Floor Construction	R Values
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
Total (R) --	_____

Total Area

Length (L)_____ft

Width (W) _____ft

Total Area (A) = L x W

A = _____sq. ft.

Heat Loss Calculations

Floor Exposure Factor (Fe) = _____

Total degree days per heating season (Dt) = _____

Heat loss per season (Qs) = $\frac{24 \times A \times Dt \times Fe}{R}$

$Qs = \frac{24 \times (\quad) \times (\quad) \times (\quad)}{(\quad)} =$ _____BTU

Total conductant heat loss: floor = _____BTU

Conductant Heat Loss Worksheet: Windows and Doors

Type of Window or Door	R Value	Height(H)	Width(W)	Number(N)	Area(A) (A-HxWxN)	Heat Loss Rate (Lr) (Lr=A÷R)
					Total --	

Heat Loss Calculations

Total degree days per heating season (Dt) = _____

Heat loss per season (Qs) = 24 x Dt x Lr

Qs = 24 x ( ) x ( ) = _____BTU

Total conductant heat loss: windows and doors = _____BTU

Conductant Heat Loss Worksheet: Walls

Wall Construction	R Values
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
Total (R) --	_____

Total Area

Height (H) = _____ ft at walls

Perimeter (P) = _____ ft of building

Gross Area (Ag) = H x P

Gross Area (Ag) _____ sq. ft.

Net Wall Area (A) = Ag minus window and door area

Net Wall Area (A) = _____ sq. ft.

Heat Loss Calculations

Total degree days per heating season (Dt) = _____

Heat loss per season (Qs) = $\frac{24 \times A \times Dt}{R}$

Qs = $\frac{24 \times (\quad) \times (\quad)}{(\quad)}$ = _____ BTU

Total conductant heat loss: walls = _____ BTU

Convectant Heat Loss Data Sheet: Windows and Doors

Infiltration or drafts can be a major heat loss factor in a home. It is not, however, advisable to completely eliminate building drafts. A constant fresh air supply is needed to maintain a healthful environment and water vapor build-up must have an outlet. One complete turnover of air per hour is a typical recommendation.

To calculate the total volume (Vt) of air leakage, first measure the total crack length (L) around your windows. Use the Air Infiltration table below and the formula Vt = L x V (where V - the air leakage rate) to calculate the total leakage per hour.

AIR INFILTRATION THROUGH WINDOWS[1]

Window Type	Remarks	Air Leakage (V)[2] at Wind Speed (mph) 5	10	15	20	25
Double-hung wood sash	Average fitted,[3] non-weatherstripped	7	21	39	59	80
	Average fitted,[3] weatherstripped	4	13	24	36	49
	Poorly fitted,[4] non-weatherstripped	27	69	111	154	199
	Poorly fitted,[4] weatherstripped	6	19	34	51	71
Double-hung metal sash	Non-weatherstripped	20	47	74	104	137
	Weatherstripped	6	19	32	46	60
Rolled-section steel sash	Industrial pivoted[3]	52	108	176	244	304
	Residential casement[5]	14	32	52	76	100

[1]Adapted from: Anderson, The Solar Home Book, 1976
[2]Air leakage, V, is measured in cubic feet of air per foot of crack per hour.
[3]Crack = 1/16 inch [4]Crack = 3/32 inch [5]Crack = 1/32 inch

The actual heat loss in BTUs (Q) is relative to the total infiltration rate (Vt), the difference between inside and outside temperatures (ΔT), the heat capacity (C) of air (C = 0.018 BTU/ft^3/°F), and the length of time in hours (h) of heat loss. The following formula is used:

$$Q = C \times Vt \times h \times \Delta T$$

The total heating season heat loss is calculated by substituting total degree hours (24 x Total Degree Days (Dt)) for total hours of heat loss (h) and the difference between inside and outside temperatures (ΔT):

$$Q = C \times Vt \times 24 \times Dt$$

Convectant Heat Loss Worksheet: Windows and Doors

Separate calculations may be necessary for windows and doors if window construction varies.

Heat capacity of air (C) = 0.018 BTU/ft^3/°F.

Total heating season degree days (Dt) = _____

Window/Door Type	Total Crack Length (L) (in feet)	Leakage Rate Per Ft. (V) (from data sheet)	Leakage Rate (V_R = L x V)

Total Window and Door Leakage Rate (Vwd) = _____ ft^3/hr

Total heat loss (Q) = C x Vwd x 24 x Dt

0.018 x ( ) x 24 x ( ) = _____ BTU

Total convectant heat loss: windows and doors = _____ BTU

Convectant Heat Loss Worksheet: Foundation

Convectant, infiltrative, heat losses occur through cracks in buildings, primarily around windows and doors, in the foundation, or in the walls. Use the table below to estimate the foundation convectant heat loss.

Type of Foundation	Condition	Air Exchange Rate, Air Changes Per Hour
Cellar	Tight, no cracks, caulked sills, sealed cellar windows, no grade entrance leaks	.25
	Some foundation cracks, loose cellar windows, grade entrance not tight	.50
	Major foundation cracks, poor seal around grade entrance	.75
Crawl Space	Plywood floor, no trap door leaks, no leaks around water, sewer, and electrical openings	.25
	Tongue-and-groove board floor, reasonable fit on trap doors, around pipes	.50
	Board floor, loose fit around pipes	.75

Heat Loss Calculations

Heat capacity of air (C) = 0.018 BTU/ft^3/°F.

Total heating season degree days (Dt) = _____

Foundation air exchange rate = _____

Volume of heated portion of house (P) = Length (L) x Width (W) x Height (H)

P = ( ) x ( ) x ( ) = _____ ft^3

Total foundation leakage rate (Vf) = (foundation air exchange rate) x P

Vf = ( ) x ( ) = _____ ft^3/hr.

Total heat loss (Q) = C x Vf x 24 x Dt

Q = 0.018 x ( ) x 24 x ( ) = _____ BTU

Total convectant heat loss: foundation = _____ BTU

Convectant Heat Loss Worksheet: Walls

Convectant, infiltrative, heat losses occur through cracks in buildings, primarily around windows and doors, in the foundation, or in the walls. Use the table below to estimate the convectant heat loss through walls.

Condition of Walls	Air Exchange Rate, Air Changes Per Hour
Caulked windows and doors, building paper used under siding	.25
Caulking in poor repair, building needs paint	.50
No indication of building paper, evident cracks around door and window frames	.75

Heat Loss Calculations

Heat capacity of air (C) = 0.018 BTU/ft^3/°F.

Total heating season degree days (Dt) = _____

Wall air exchange rate = _____

Volume of heated portion of house (P) = Length (L) x Width (W) x Height (H).

P = ( ) x ( ) x ( ) = _____ ft^3

Total wall leakage rate (Vw) = (wall air exchange rate) x P.

Vw = ( ) x ( ) = _____ ft^3/hr.

Total heat loss (Q) = C x Vw x 24 x Dt.

Q = 0.018 x ( ) x 24 x ( ) = _____ BTU

Total convectant heat loss: walls = _____ BTU

Infiltrative Air Exchange Summary

Having determined the total air leakage rates for windows and doors, foundation, and walls you are now in a position to decide whether or not these rates are acceptable. In order to maintain an ample fresh air supply, a typical air exchange rate recommendation is one complete turnover of air per hour.

Total window and door leakage rate (Vwd) = _____ $ft^3/hr.$

Total foundation leakage rate (Vf) = _____ $ft^3/hr.$

Total wall leakage rate (Vw) = _____ $ft^3/hr.$

Grand total leakage rate (Vt) = _____ $ft^3/hr.$
(Vt = Vwd + Vf + Vw)

Your grand total leakage rate (Vt) should now be compared to the overall heated volume of your house. The house volume can be computed by multiplying the length (L) x the width (W) x the height (H) of the heated portion of your house.

P = L x W x H

P = ( ) x ( ) x ( ) = _____ ft^3

Now calculate the air changes/hr. by dividing the grand total leakage rate (Vt) by the heated volume of your house (P).

Changes/hr. = Vt ÷ P

( ) ÷ ( ) = _____ Changes/hr.

Heat Loss Summary

Fuel type and BTU content (check one):

	Fuel	BTU/Unit
_____	Coal	2.5×10^7 BTU/ton
_____	#2 Fuel Oil	1.4×10^5 BTU/gal.
_____	Natural Gas	1.1×10^3 BTU/ft^3
_____	Electricity	3.4×10^3 BTU/kwh
_____	Wood	2.0×10^7 BTU/cord

Furnace Efficiency (check one):

	Heater	Efficiency
_____	Heat pump	2.00
_____	Electric baseboard	1.00
_____	Home gas furnace	.85
_____	Home oil furnace	.65
_____	Stoker-fired coal	.60
_____	Air-tight wood stove	.50
_____	Simple box stove	.30
_____	Fireplace/circulator	.20
_____	Fireplace	.10

Fuel-furnace factor (Z) = BTU/unit x efficiency = _____

Fuel cost/unit (check your latest bill) (S) = _____ $/ton, gal, ft^3, kwh, or cord

	Heat loss per season (Qs) (from previous worksheets)	Fuel needed per season (F) (F=Qs÷ Z)	Fuel cost per season ($) ($=F x S)
Conduction			
Ceiling	_____ BTU	_____	$_____
Floor	_____ BTU	_____	$_____
Windows & Doors	_____ BTU	_____	$_____
Walls	_____ BTU	_____	$_____
Convection			
Windows & Doors	_____ BTU	_____	$_____
Foundation	_____ BTU	_____	$_____
Walls	_____ BTU	_____	$_____
TOTALS	_____ BTU	_____ ton, gal, ft^3, kwh, or cord	$_____

ROI (Return On Investment)

Once you've calculated how much heat you're losing and how much that heat costs, you have the option of doing something about it or not. The decision is not always simple though. You usually also want to know how much a proposed improvement will cost, how much it will save, and how quickly you will recover your investment.

Basically we need to know three things: the current fuel cost per year for the component in question, the projected fuel cost per year with improvement, and the total cost of the improvement. The return on investment (ROI) equals the yearly savings (current fuel cost (C) minus the projected fuel cost (P)) divided by the cost of the improvement (I). The resulting fraction shows the proportion of the original investment that is regained each year. To change that to a percentage, simply multiply by 100.

$$ROI = \frac{C - P}{I}$$

Another useful piece of information is the payback period, in other words, the time required for your investment costs and your savings to balance. The payback period (payback) is calculated by dividing the cost of the improvement (I) by the yearly savings (current fuel cost (C) minus projected fuel cost (P)). Here the resulting figure tells you the number of years it will take to completely regain your investment money. You'll notice that the payback period is the mathematical inverse of the return on investment.

$$payback = \frac{I}{C - P}$$

As an example let's consider a single pane window (2.5' x 4') to be changed to double pane, in the Philadelphia area, in a house heated by oil.

1. window area = 2.5' x 4' = 10 sq. ft.
2. current R value = 1
3. improved R value = 2
4. yearly degree days = 5,100
5. current seasonal heat loss = $\frac{24 \times 5{,}100 \times 10}{1}$ = 1,224,000 BTU
6. projected seasonal heat loss = $\frac{24 \times 5{,}100 \times 10}{2}$ = 612,000 BTU
7. cost of fuel per gallon = $.95/gal.
8. #2 fuel oil BTU content = 1.4×10^5 BTU/gal.
9. home oil furnace efficiency = .65
10. current seasonal fuel cost = $\frac{1{,}224{,}000 \times .95}{1.4 \times 10^5 \times .65}$ = $12.78
11. projected seasonal fuel cost = $\frac{612{,}000 \times .95}{1.4 \times 10^5 \times .65}$ = $6.39
12. cost of improvement = $35.00
13. return on investment = $\frac{\$12.78 - \$6.39}{\$35.00}$ = .18 per yr. = 18% per yr.
14. payback period = $\frac{35.00}{12.78 - 6.39}$ = 5.5 yrs.

Questions:

How does your return on investment compare to the interest your money could get at the bank?

How does that same return on investment compare to the return you might get by investing in stocks?

Could you use this same general technique to analyze other possible investments (eg. commuting by bicycle rather than by car, buying a washing machine instead of using a laundry or laundromat, using a microwave oven instead of a conventional one?)

Project DETECT
by Nick Ignatuk

Like it or not, we are in the midst of an energy crisis which has no simple solution. The key to solving this problem however seems clearly to involve an expanded role of the consumer in the area of conservation. For this reason, the students of the Ridley School District in Delaware County, Pennsylvania, developed a sophisticated energy conservation program called Project DETECT (Developing Educational Talents for Energy Conservation Tactics).

The purpose of the project was to train gifted students in grades 10 to 12 in the areas of heat loss and weatherization techniques and the analysis of insulation types and materials, and then to have the students use this knowledge by surveying homes in the community for insulation and weatherization needs. The students developed a comprehensive homeowner checklist which was distributed to interested members of the community, completed and then mailed back to the school. Upon receipt of the completed checklists, a team of students surveyed the homes with an infrared point scanning device which enabled the students to accurately determine the amount of heat escaping through walls, ceilings, windows and doors. With this instrument the total amount of wall and ceiling insulation can be calculated and the R-value determined without knowing insulation types or thicknesses, but rather by quick and simple temperature measurements. Students also check the homes for caulking and weatherstripping needs as well as the existence of storm windows.

All of this information is recorded and returned to a student analysis team at the high school. This team developed a sophisticated computer program into which the information is fed. This program produces a detailed heat loss analysis of the home which includes the estimated heating costs per season and a breakdown of the costs to heat the home due to heat escaping from walls, ceilings, windows, doors and due to infiltration in general. Each of these areas also shows a projected costs savings due to possible improvements suggested by the students. The total heat and cost savings per year were reported along with the projected "pay-off" time if the given improvements were made. This analysis and energy tips information are sent to the homeowner free of charge.

In addition to conducting these free home heating surveys, the students sponsored an elementary school essay contest in which students in grades 3 through 6 were invited to write in 200 words or less how they, as children, could save energy at home and at school. Over 500 essays were submitted and winners from each grade were selected and awarded energy related prizes over the school's closed circuit television. Some of the childrens' comments included: "Please consider our future. Save us the energy our generation deserves."; "I hope that people will find some new energy sources, but until they do, we have to be very careful with what we've got."; "In order to have a bright future, we must "turn off" so that we can "turn on" in the 21st century."; "It is the job of we younger Americans to teach our parents conservation. They've been wasting energy long enough!".

Project DETECT has been a part of the Learning Enrichment Program of the Ridley Senior High School. This is a program designed for gifted students and has involved the science oriented students in the program in a meaningful community interest project. We feel that a project like DETECT need not be conducted only by gifted students however, but could be done in most any school either as a club or classroom project. Basic heat loss information and weatherization analysis is all that is needed as well as local publicity to inform the community of the availability of the project.

We are grateful to the several area newspapers and television stations that featured articles and programs about this project as well as to the Associated Press and the United Press wire services for carrying the story.

SOLAR ENERGY

Humanity has always and continues to depend heavily on the sun's energy. The sun drives the winds and evaporates water from the ocean creating the rains which nourish the inlands. The sun provides energy in a form which chlorophyl can utilize to create the chemical bond energy that plants, and later animals, require. It was ancient sun-powered plant systems which provided the excess production which we mine today as coal, oil, or gas. About the only non-solar energy in use today is generated geothermally or by nuclear fission. The vast majority of the sun's available energy is lost by reradiation to space as heat or light before it ever serves a useful function to humanity.

Lately, substantial interest has developed in the use of some of that wasted solar energy. The activities which follow will introduce you to some basic thermal applications of solar energy as well as help you to analyze some fundamental impacts of solar energy on small scale climatic variations.

TEACHING NOTES:

Several Simple Solar Studies

As the title suggests, these four experiments are quite simple. Required materials are nothing more than construction paper of various colors, tape, thermometers, tin cans, paint, and miscellaneous materials such as sand, salt, water, or air. The only other required ingredient is sunlight. In general students are asked to test various colors, orientations, and masses for their solar-thermal properties.

Cardboard Collectors

Much of solar thermal technology is straight forward enough that students can easily build working collectors. The individual information sheets are pruposely sketchy; exact dimensions and designs are not as important as student innovations. Students should be encouraged to experiment and add their own refinements. If a variety of collector designs emerges from a class then you have a strong basis for comparison, analysis, and discussion of varying performances.

Most of the necessary material can be collected for free, the rest is inexpensive. Following is a check list of materials you may wish to have on hand, depending on the collectors to be built and your budget:

Basic Structure

Cardboard (various size boxes of various strength)
Wood strips
Plywood scraps
Coat hanger wire
Other wire
Miscellaneous tape & glue
String
Window screen scraps

Glazing

- Clear plastic food wrap
- Translucent plastic sheeting
- Mylar sheets for storm windows
- Plexiglass scraps

Reflectors

- Aluminum foil
- Aluminized mylar
- Used offset printing plates
- Any shiny sheet metal

Containers

- Metal cans
- Glass jars
- Plastic bottles
- Cardboard tubes
- Black plastic bags

Thermal Mass

- Salt
- Sand
- Gravel
- Bricks
- Water

Insulation

- Newspaper
- Cardboard
- Styrofoam packing
- Foam plastic sheets
- Vermiculite
- Dacron stuffing
- Straw
- Dry leaves

Color

- Colored construction paper
- Tempera paints
- Spray paint

Tools

- Utility knives
- Scissors
- Pliers
- Wire cutters
- Tin snips
- Staple guns
- Yard (meter) sticks
- Carpenter's squares
- Protractors
- Compasses
- Pencils

Just as the information sheets are sketchy, so is the introductory information. Rather than bore the kids with masses of technical information, we would rather provide a rudimentary working knowledge and allow the students the luxury of discovery and invention as they pursue their individual projects. As opposed to the standard science experiment, here the outcomes are not always predicted by the students. Some projects may "fail", but their apparent failure is really an opportunity for the students to learn by consideration of design alternatives.

To introduce these projects, you may wish to start with the First Law of Solar Energy: "Put something in the sun and it will get hot." To be sure, there are many other factors that ultimately determine how effective any particular apparatus is. Those other factors are what the students should be discovering with their projects.

Flat Plate Solar Collector

This construction is about as basic as you can get. All it does is heat up air and with the vent valves open you should be able to feel a draft as the collector thermosyphons (warm air rising and creating a slight draft). Because of the collector's simplicity, here is an excellent chance to experiment with controlled variables. Several possibilities are mentioned on the information sheet. Glazing refers to the transparent or translucent material used to cover the face of the collector. Insulation can be used on the sides and back of the collector to prevent heat loss. Students in one of our programs built a large collector (15' x 8'), insulated it with styrofoam, and melted the styrofoam the first time they tried the collector. They failed to vent the collector adequately, it stagnated, over heated and consequently damaged inadequate materials. Despite their apparent failure, a tremendous amount of learning occurred. Your collectors should get hot ($\sim$120°F), but not that hot. Simply opening or closing a vent will allow you to control the temperature of your collector. The orientation of your collector (the compass direction is faces) will dramatically affect the amount of energy you are able to collect. You may wish to periodically change your collector's orientation as the sun moves across the sky (track the sun). The tilt angle of the collector can also be adjusted as the sun is higher or lower in the sky.

Solar Fruit Dryers

These projects are a step up in complexity from the flat plate collectors. Here we want to heat air and use it to dry fruits such as apples, bananas, or peaches. You will also need to maintain air flow to keep the air from saturating with moisture. This can be done by using drying racks made of window screen and by providing ample vent openings. The sketches suggest several possible designs. The interiors of some dryers have been painted black to heat the interior air. Other dryers were lined with aluminum foil to reflect the light directly onto the fruit. On good sunny days, we've been able to dry thin apple and banana slices in an afternoon.

Solar Still

Here we are using a low temperature evaporation/condensation cycle to extract clean water from dirty water. Line a shallow box with black plastic, place a receiving container on a stand in the center, add dirty water to

the box, cover it all with clear plastic, place a small stone on the clear plastic cover to make it sag over the receiving container, place it all in the sun, and wait. Before long you should be surprised at the amount of distilled water you've collected. You might try placing a bottomless still over grass, wet sand, or mud. You should be able to collect water from these natural sources. Even without a box you can still build a still. Just dig a hole in the ground, place your receiving container and stretch and weight the clear plastic. Moisture from the soil should slowly fill your cup.

Solar Hot Cone Hot Dogger

This is a simple concentrating collector. Soil is used to reflect more sunlight onto a central column than that area would receive directly from the sun. The concept of a cone reflecting sunlight to a central column is easy to visualize with this project. The optimum interior angle for the cone is 90 degrees but you may wish to allow the students to experiment with a variety of angles.

With any concentrating collector a critical construction concern is the reflector. For optimum performance the reflector must be smooth and uniform. If you are using foil on cardboard, make sure the foil lies flat, not wrinkled, and the cardboard curves evenly, not erratically. You will probably need to glue down the whole under-surface of the foil to keep it smooth.

Another concern common to concentrating collectors is orientation and inclination. If the collector does not accurately track (follow) the sun, the focal point will not be properly heated. Aligning this collector is readily accomplished by positioning it such the shadow of the object to be cooked falls on the apex of the cone.

Try cooking hot dogs, marshmallows, or mushrooms.

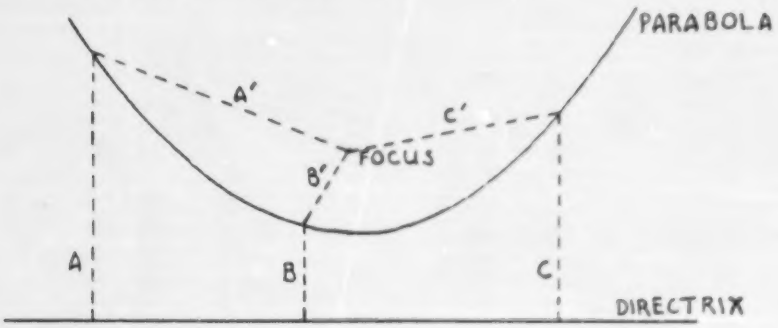
Solar Oven Donut

This is essentially the same collector as the Hot Cone. The differences are that this collector is much larger, the apex of the cone is removed, and it focusses on a can which serves as an oven. The larger the diameter of the ring, the hotter your oven will get. Again, smoothness and uniformity are critical to the reflector.

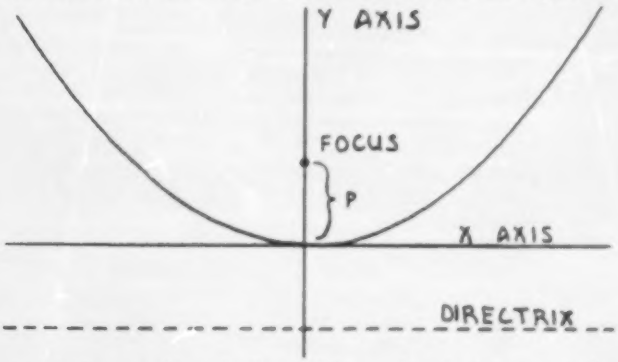
How to Draw a Parabola

Of the various reflector shapes used in concentrating collectors, the parabola is the most efficient. Properly aligned, the parabola will focus the parallel rays of the sun on a single point. You won't collect any more energy than you could with a flat plate collector of the same size, but you will be able to get higher temperatures in the smaller volume of material at the focus. The parabolic shape is therefore important in high temperature applications, such as boiling water and cooking. To achieve maximum temperatures you will need a large collector with a very accurate focus. Additionally the object to be heated should be of low thermal mass (two pints of water will heat more slowly than one pint of water).

The parabola is defined as a curve equidistant from a point (the focus) and a straignt line (the directrix).



Mathematically the parabola can be described by the equation $Y = 4p\ X^2$ where p is the distance of the focus from the nearest part of the curve.



By using the instructions on the information sheet you can draw a parabola of any size. You need only adjust the focus to change the size of the collector. In theory, a collector of infinite size could be constructed from any particular focus by extending the arms of the parabola to infinity. In practice that would be impossible, or at least a tremendous waste of material. The arms of most practical collectors don't project beyond the focus. A focus of five inches or more should give you a useful collector. Again, experiment and try a variety.

Parabola Template

Use this template if you don't need a larger collector and if you'd rather not draw your own.

Parabolic Solar Collectors

The parabolic curve is used in primarily two types of solar collectors. The cylindrical type and the disc type. The cylindrical type is often used to heat water -- while the disc type is used for cooking and in large installations for high temperature applications. Use your parabolic curve templates to

cut support ribs for either type of collector. In the cylindrical type, the ribs should be arranged parallel to each other in a row. The disc type collector requires the ribs to be arranged radially. Since you've gone to the extra trouble of cutting out sophisticated curves for the ribs, continue the special attention by attaching the reflecting surface as securely and smoothly as possible. Any wrinkles, boils, or creases will tend to scatter the light rather than accurately reflect it.

Great International Passive Solar Heated Doll House Contest

Our philosophy with doll houses is much the same as our philosophy with the cardboard collectors: direct student involvement and experience is more important than a student's abstract accumulation of facts. Consequently, we encourage a minimum of pre-construction lecture. Let the refinements in knowledge come from student questions, mistakes, and discoveries.

We usually discuss four major factors of solar design: collection, storage, distribution, and retention. The collection aspects relate to a house's ability to allow sunlight in, without which there can be no heating effect. Once the energy is inside the building, it must be stored somewhere. Anything with mass, air included, will store that heat energy, but typically a more massive object will store more heat. Therefore some type of thermal mass (stone, sand, water) should be included in the house design. People, and dolls, don't usually live within the storage medium, so some method should be provided to distribute your collected and stored energy. This is most easily done by placing the storage within the living space and allowing the heat to naturally radiate. Once that heat has progressed through three major steps just to heat the living room, there is real reason to want to retain it. This is where good insulation and tight construction come in.

Once the houses are completed, they all are placed in the sun simultaneously. With thermometers in the living spaces, individual temperatures can be monitored. The usual objective of the contest is to find the house which stays the hottest longest. After all houses have been exposed for a set interval (one hour is usually ample), temperatures are recorded and the houses are moved indoors or to some other cooler spot. Temperatures are now monitored every 15 minutes for the next two hours (or set your own schedule). By the end of the period most houses will probably have stabilized at ambient temperature and a few may still be warmer. Here's your chance to discuss why. You could use the collection/storage/distribution/retention model for a discussion framework.

Rather than look for the house that stays the hottest longest, you might design for the coolest house, look for the hottest thermal mass, or try to build a house that would provide normal humans a comfortable temperature range.

Microclimates

It is commonly accepted that the climate of Florida is different than that of Maine. It is not so well known though, that the north side of a ravine can be greatly different from the south side. This can be easily studied by

monitoring such factors as temperature, light, moisture, and wind. The results can in turn help in the siting of a house, the establishment of windbreaks, and the planting of gardens.

Solar Constant?

This activity will allow you to measure the available solar energy at any particular moment at any particular site. A light meter is a necessity, preferably one that measures in footcandles. A standard photographer's light meter, or camera with a light meter, will do, however.

Alternatives

In 1977-78 a science teacher, Jim Wakefield, and an industrial arts teacher, Jack Roberts, from North Middle School in West Chester, Pennsylvania, collaborated on a year-long energy project for 7th and 8th graders. This is their year end report.

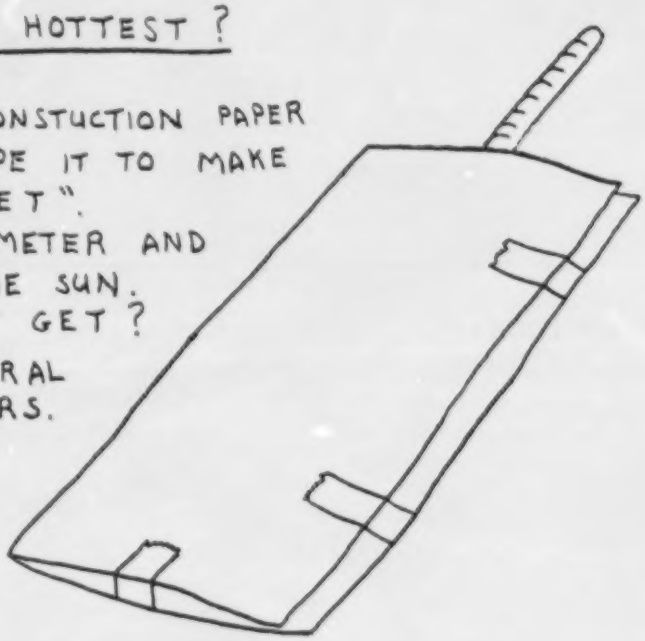
Alternative Energy E-Lab I & II

Another project has been continually evolving since 1976 at Faust Elementary School in Bensalem, Pennsylvania. The principal, Bob Capron, and several teachers lead by Jacquelin Blum have been working with students from kindergarten through grade 5. The first report discusses activities in 1976-77 and the second covers the 1978-79 school year. The program continued unabated in 1977-78 but without the official assistance of Project E3. Consequently, no final report is available for that year.

SEVERAL SIMPLE SOLAR STUDIES

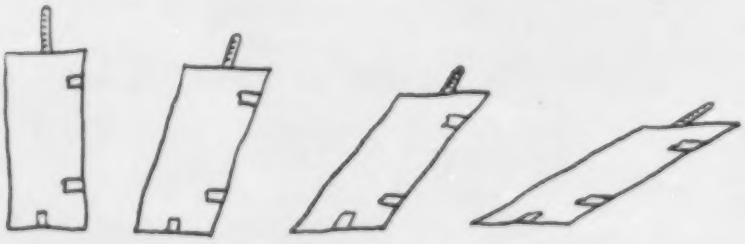
WHAT COLOR GETS HOTTEST ?

- FOLD A SHEET OF CONSTUCTION PAPER IN HALF AND TAPE IT TO MAKE A "SOLAR WALLET".
- INSERT A THERMOMETER AND PLACE IT IN THE SUN.
- HOW HOT DOES IT GET ?
- TRY TESTING SEVERAL DIFFERENT COLORS.
- WHICH ONE GETS HOTTEST ?



WHAT ANGLE MAKES THE WALLETS HOTTEST ?

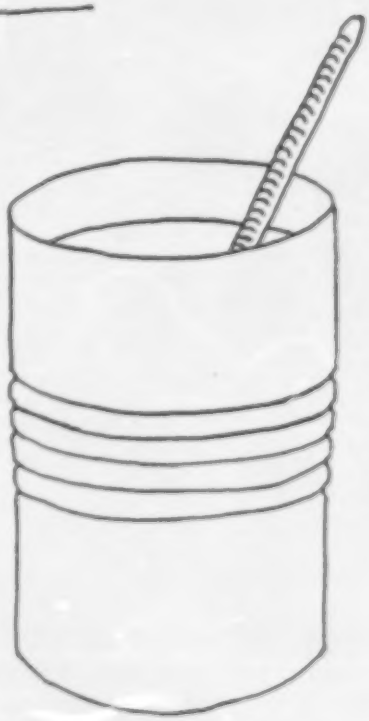
- MAKE SEVERAL "SOLAR WALLETS" OF YOUR HOTTEST COLOR.
- PLACE THEM ALL IN THE SUN BUT WITH EACH PROPPED AT A DIFFERENT ANGLE. BE SURE THAT EACH FACES THE SUN AS DIRECTLY AS POSSIBLE.
- WHICH ANGLE GETS HOTTEST ?



WHAT ORIENTATION MAKES THE WALLETS HOTTEST ?

- PROP ALL YOUR "SOLAR WALLETS" AT THE HOTTEST ANGLE DISCOVERED FROM THE LAST EXPERIMENT.
- POINT ONE DIRECTLY TOWARD THE SUN, ONE DIRECTLY AWAY FROM THE SUN, AND THE REST IN VARIOUS DIRECTIONS IN BETWEEN.
- WHICH ONE GETS HOTTEST ?
- DOES THE SAME ONE STAY THE HOTTEST ALL DAY LONG ?

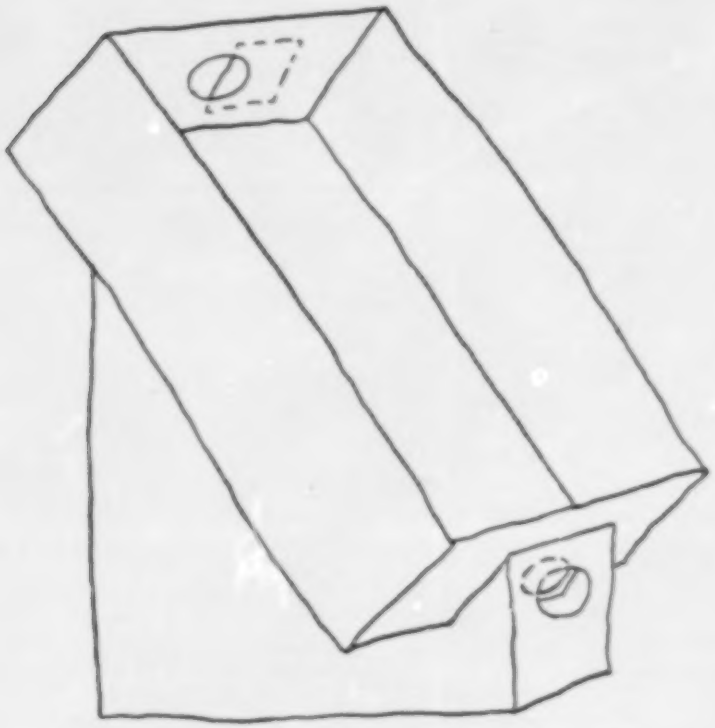
WHAT MATERIAL STAYS HOTTEST ?

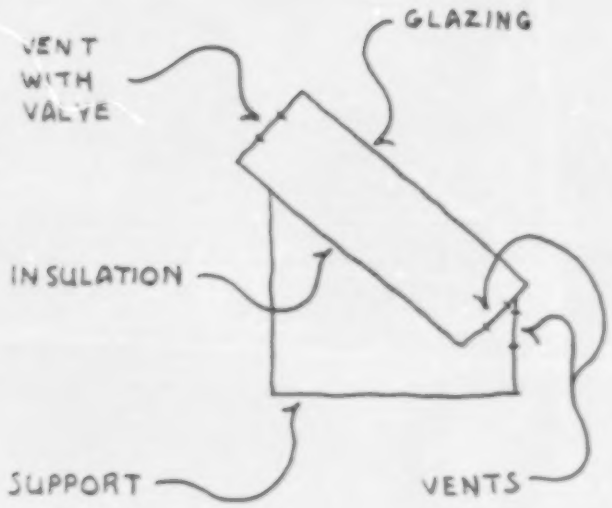


- USE YOUR HOTTEST COLOR TO PAINT SEVERAL TIN CANS ; BE SURE YOUR CANS ARE THE SAME SIZE.
- FILL THE CANS WITH VARIOUS MATERIALS, SUCH AS SAND, SALT, WATER, OR AIR.
- INSERT A THERMOMETER AND PLACE EACH IN THE SUN.
- AFTER 30 MINUTES OR SO, TAKE THE CANS OUT OF THE SUN.
- CHECK THE TEMPERATURE OF EACH CAN AND RECHECK ALL TEMPERATURES EVERY 5 MINUTES UNTIL THEY ALL COOL TO ROOM TEMPERATURE.
- WHICH ONE STAYED WARMEST LONGEST ?

Solar Energy 68

FLAT PLATE SOLAR COLLECTOR

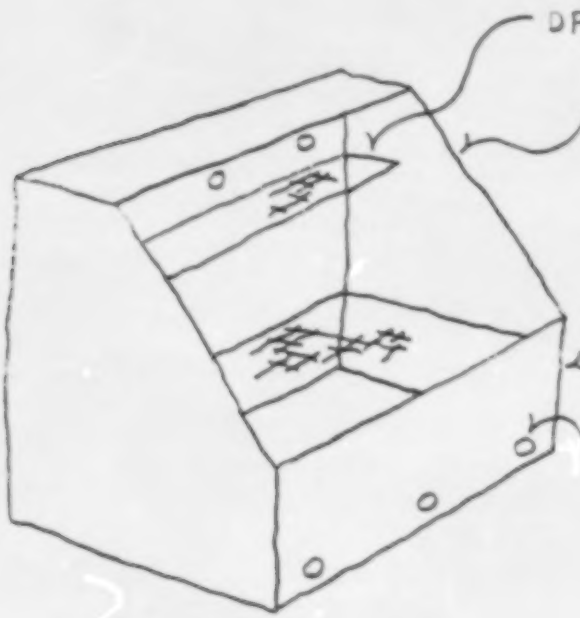




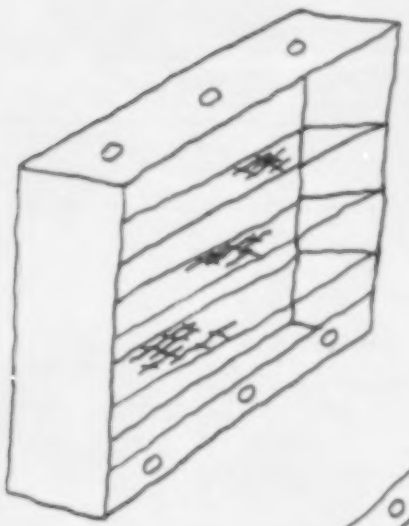
EXPERIMENTAL VARIABLES:

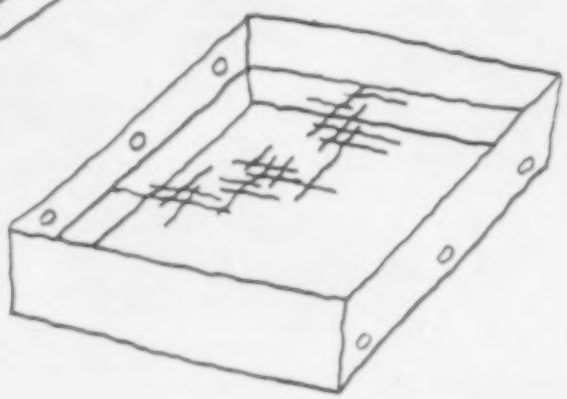
- GLAZING (TYPE, NUMBER OF PANES, SPACING)
- INSULATION (STYROFOAM, VERMICULITE, CARDBOARD, ETC.)
- VENTING (PLACEMENT, SIZE, CONTROL)
- ORIENTATION
- TILT ANGLE

SOLAR FRUIT DRYERS

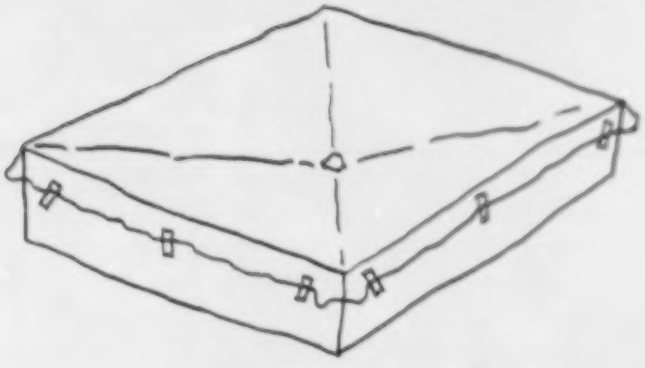


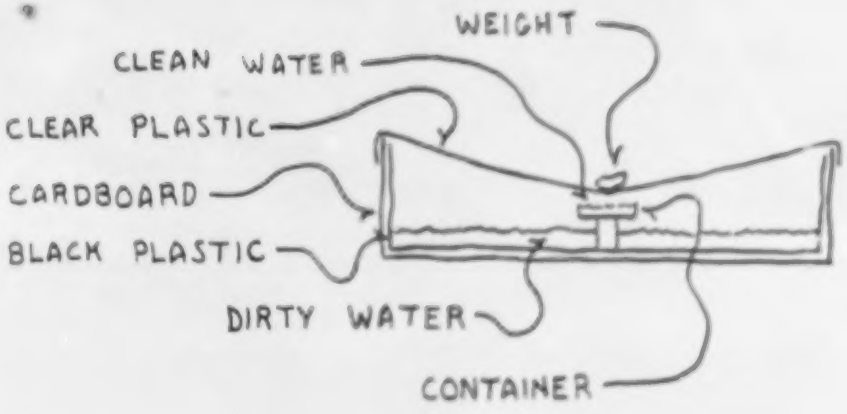
EXPERIMENTAL VARIABLES:
- ANGLE OF FRONT GLAZING
- PLACEMENT OF DRYING TRAY(S)
- NUMBER OF LOWER VENTS
- NUMBER OF UPPER VENTS
- COLOR OF INTERIOR

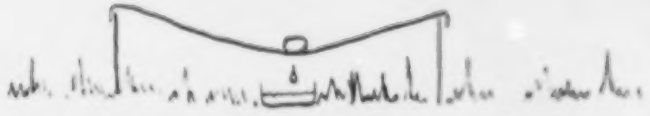




SOLAR STILL



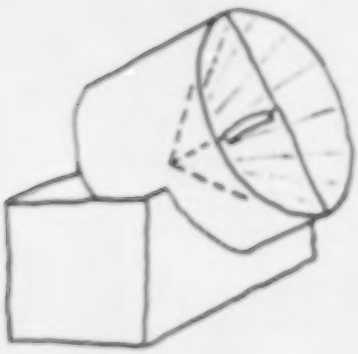


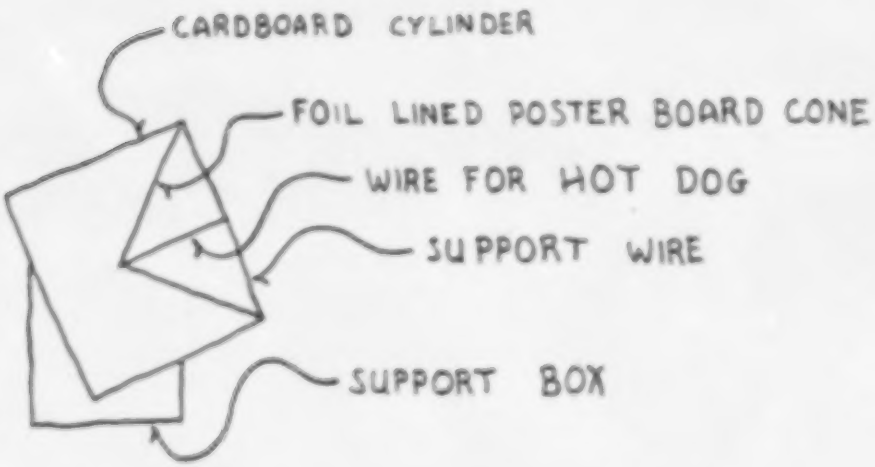


OR, PLACE BOTTOMLESS STILL OVER GRASS, WET SAND, MUD, ETC.

OR, DIG HOLE IN GROUND

SOLAR HOT CONE HOT DOGGER

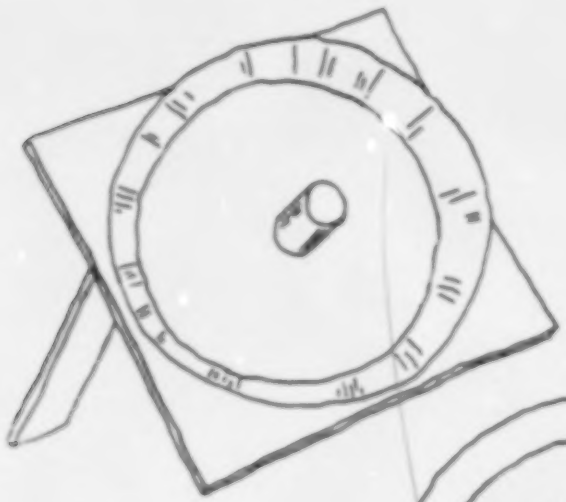




EXPERIMENTAL VARIABLES :

ORIENTATION
INCLINATION
INTERIOR ANGLE OF CONE
DIAMETER OF CONE
REFLECTING MATERIAL

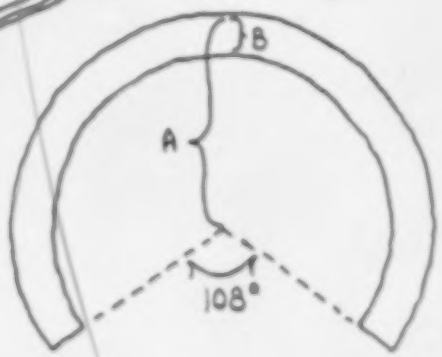
SOLAR OVEN DONUT



CUT A "C" FROM FLAT POSTER BOARD AND JOIN ENDS TO FORM FUNNEL-LIKE RING

A - LONGER IS HOTTER

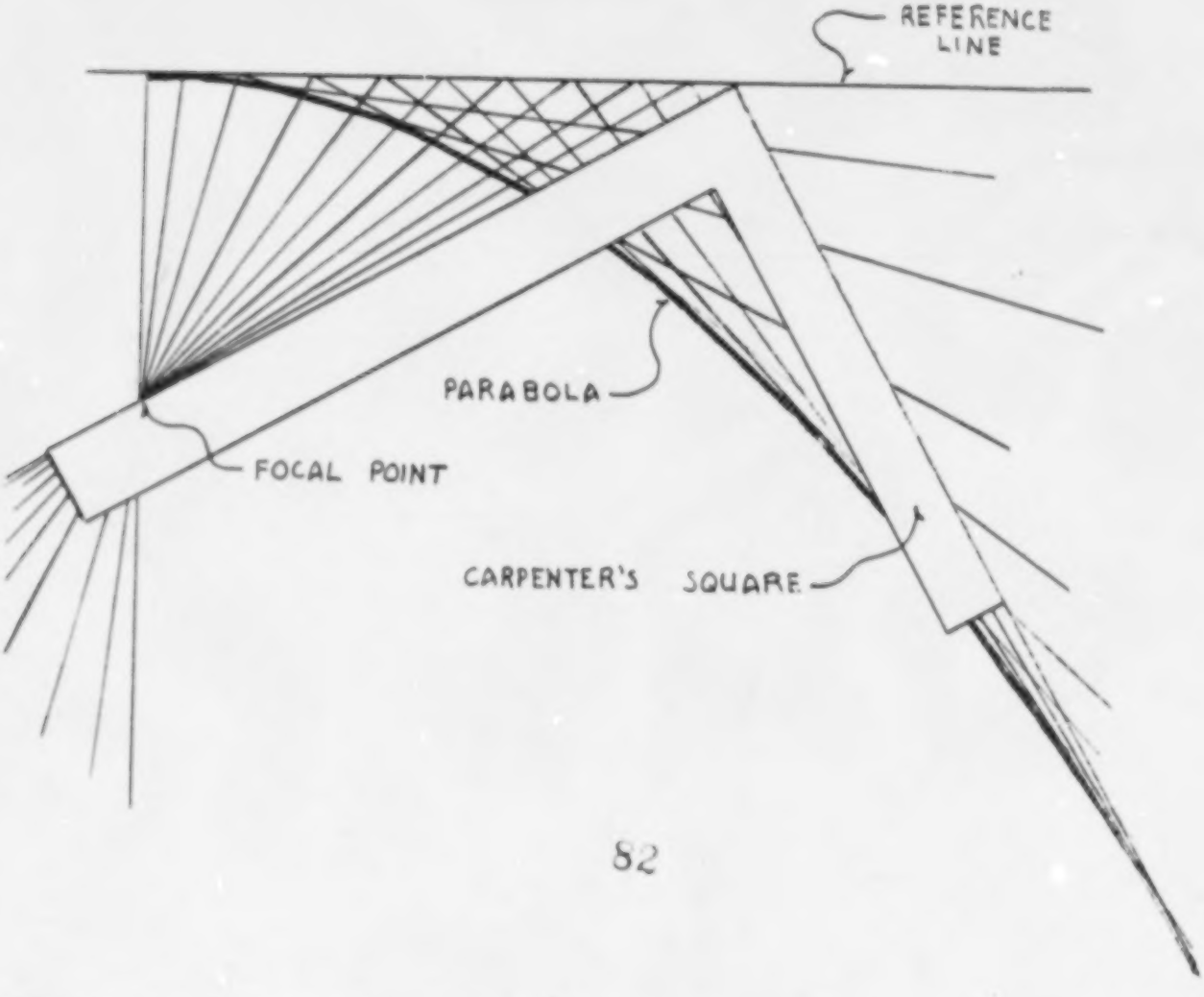
B - 1.5 × HEIGHT OF OVEN



RING CUT-OUT PATTERN

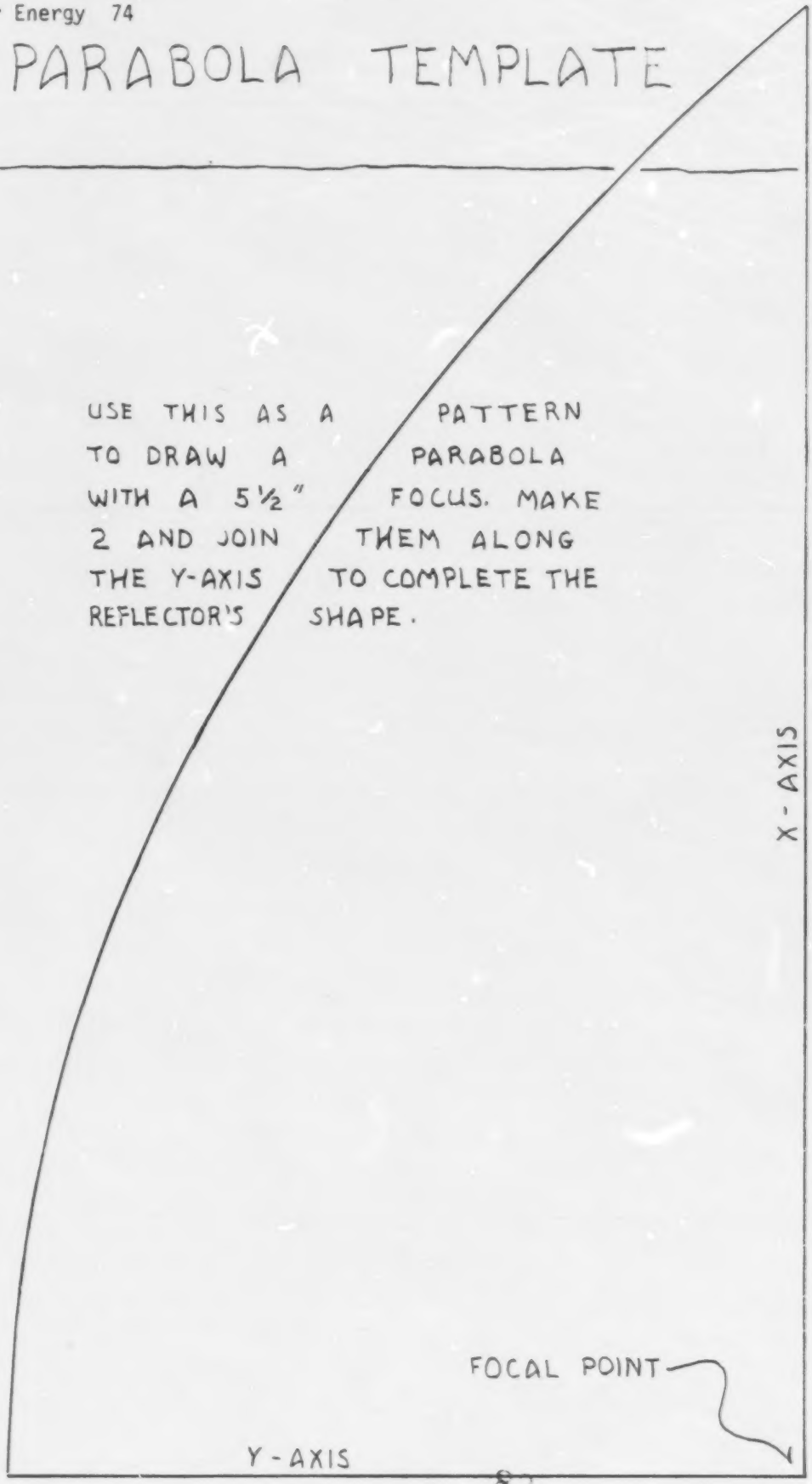
HOW TO DRAW A PARABOLA

1. DRAW A LINE NEAR THE EDGE OF YOUR TEMPLATE PAPER.
2. SELECT A FOCAL DISTANCE (5" OR MORE) AND MARK A POINT THAT DISTANCE FROM THE LINE.
3. FIND A CARPENTER'S SQUARE OR ANY OTHER OBJECT WITH TWO EDGES AT RIGHT ANGLES TO EACH OTHER.
4. PLACE ONE EDGE OF THE CARPENTER'S SQUARE ON THE FOCAL POINT AND ITS CORNER ON THE LINE.
5. TRACE ALONG THE OUTSIDE EDGES OF THE SQUARE.
6. MOVE THE CORNER OF THE SQUARE FURTHER ALONG THE FIRST REFERENCE LINE AND TRACE AGAIN.
7. REPEAT UNTIL YOUR PARABOLIC CURVE IS LARGE ENOUGH FOR YOUR COLLECTOR

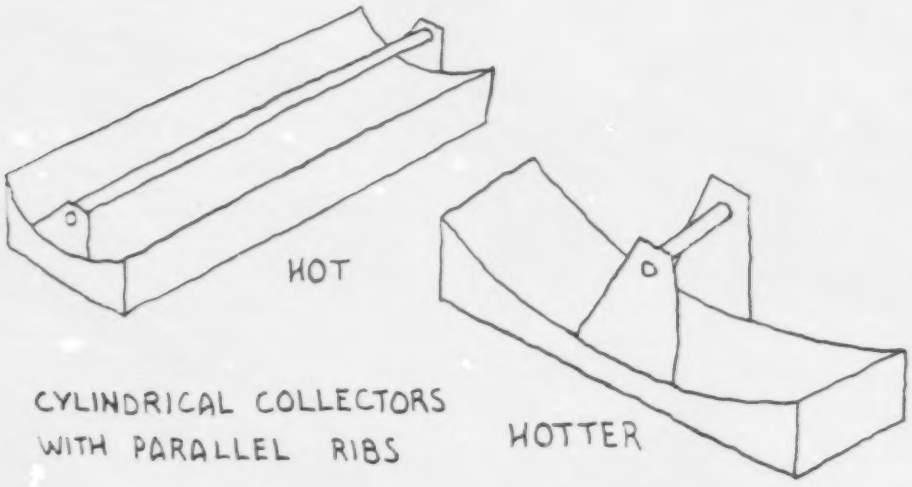


PARABOLA TEMPLATE

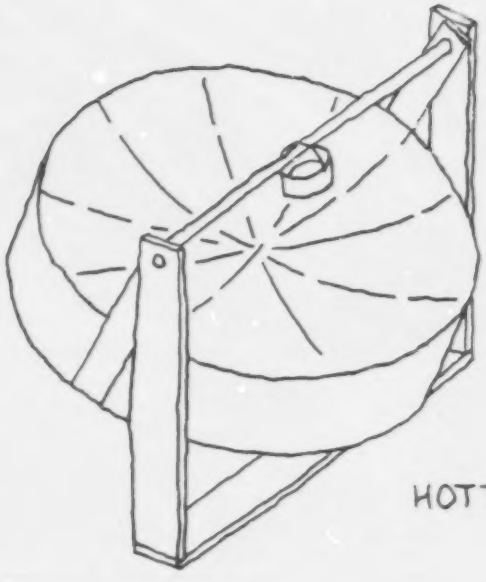
USE THIS AS A PATTERN TO DRAW A PARABOLA WITH A 5½" FOCUS. MAKE 2 AND JOIN THEM ALONG THE Y-AXIS TO COMPLETE THE REFLECTOR'S SHAPE.



PARABOLIC SOLAR COLLECTORS

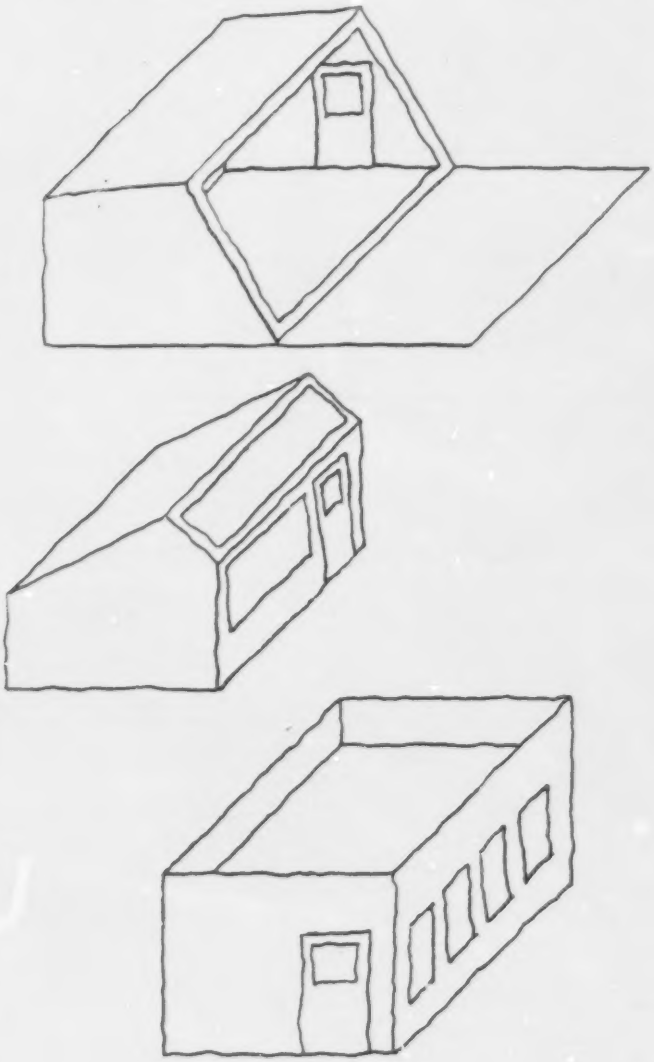


CYLINDRICAL COLLECTORS
WITH PARALLEL RIBS



DISC COLLECTOR
WITH RADIAL RIBS

GREAT INTERNATIONAL PASSIVE SOLAR HEATED DOLL HOUSE CONTEST



EXPERIMENTAL VARIABLES:
- FLOOR SHAPE
- ROOF SHAPE
- ORIENTATION
- INSULATION
  - THICKNESS
  - MATERIAL
    - CARDBOARD
    - PAPER
    - VERMICULITE
    - STYROFOAM
- INFILTRATION
- COLOR
  - INTERIOR
  - EXTERIOR
- THERMAL MASS
  - DESIGN
  - MATERIAL
    - SAND
    - SALT
    - WATER
    - PAPER
    - AIR

- PLACE IN SUN
- MEASURE TEMPERATURE AFTER 1 HR.
- MOVE TO COOL AREA OUT OF SUN
- MEASURE TEMPERATURE EVERY 15 MINS. FOR NEXT 2 HRS.

Microclimates

by Chris Reese

Introduction

Factors such as temperature, light, moisture, and wind act together to create the physical environment of a particular region. These factors determine what plants and animals may inhabit the region. However, in any region, the physical factors vary greatly from place to place. Microclimates, or micro-environments, exist in the larger environment.

For example, the temperature on a warm, sunny day is higher close to a lawn than it is a meter above. The air in a woodlot holds more moisture than the air above an adjacent field. A south-facing slope gets more sun than a north-facing one. A meadow could be flooded with light, while under a nearby grove of trees the ground is well-shaded. The chances of frosting may be greater in a hollow than on the hills around it. These microclimates generally affect living things more directly than does the overall environment.

There are many different ways that microclimate studies can be approached. The ones chosen depend on what information we want.

Following are descriptions of a general procedure for conducting a microclimate study, some equipment suggestions, and descriptions of some study possibilities.

General Procedure

1. Decide what you want to get from the study. What will the study show? What educational objectives could this activity meet?

2. Determine what equipment, if any, will be needed. Gather or make it.*

3. Develop a format for recording the data.*

4. Make plans for interpreting and discussing the results.

5. Do it. Everyone must become familiar with the objectives, the proper use of equipment, and the procedure for collecting and recording the data. Then comes the fun of gathering the data. Usually, working in small groups is the best approach.

Equipment

1. Temperature - Simply use thermometers. Remember that glass ones can break. "Dial" thermometers that use a bimetallic strip instead of mercury or alcohol are highly recommended and can be purchased with metal stems that can be pushed into soil to measure the temperature there.

*Get the students involved in as many steps of the planning, conducting, and evaluation of the activity as they are able to handle.

If the data are to be accurate, be sure the thermometers have been calibrated, or at least check to be sure that thermometers used in the same study are giving equal readings.

2. Light - Light meters are available from many educational or science supply houses. The ideal meter to use is one calibrated in foot-candles, although these tend to cost more than camera light meters. Camera light meters are fine. They read in f-stops which can easily be converted to foot-candles by using the number line provided here.

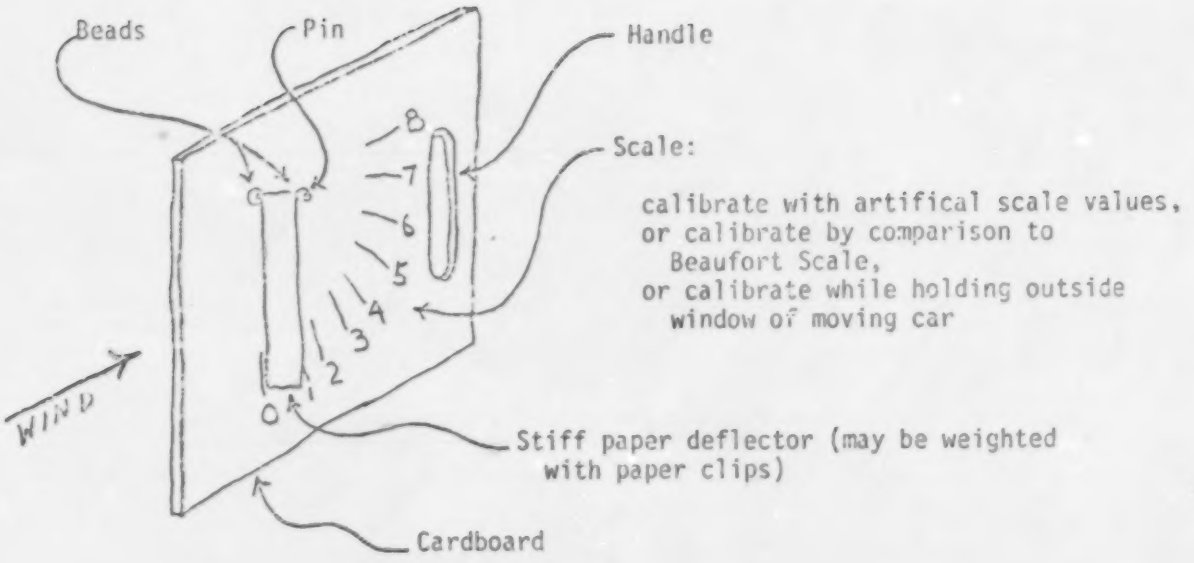
    1. Set the ASA of the camera light meter at ASA 100.
    2. Set the shutter speed at 1/60 sec.
    3. Select appropriate f-stop.

    4. Read foot-candles from number line.

Often, light meters are used by pointing the window upwards. However, this method can give erroneous results. For example, a small sun beam filtering through overhead leaves may strike the meter and give an unrepresentative, high reading. If you wish to compare light intensities in various microclimates, use the following procedure: Place a sheet of grey paper on the ground. Hold the light meter 1 meter above it with the window pointing down at the grey paper. Be sure that your shadow does not interfere with the reading.

If light meters are unavailable, another method that does not require equipment could be used in some cases. Simply lie on the ground on your back and estimate the percentage of your field of vision that is sky. A lawn, then, would be 100% open, a forest might be 5% or 20% open.

3. Wind - A simple, hand-held wind meter can be purchased through educational or scientific supply houses. A less expensive one can be made by following instructions given in any of many elementary science curriculum guides. A brief description of one model is shown on the following page.



Even simpler, is the "eyeball" method of determining wind speed by using the Beaufort Scale of Wind Force described below. However, this method is not always adequate for some studies.

Condition	Miles Per Hour	Description of Effects
calm	under 1	smoke rises vertically; nothing seems to move
light air	1-3	smoke drift shows wind direction; barely moves leaves
light breeze	4-7	can be felt on face; leaves rustle; small twigs move
gentle breeze	8-12	leaves and small twigs in constant motion; dry leaves and paper are blown up from the ground
moderate breeze	13-18	moves small branches; raises dust and paper and drives them along
fresh breeze	19-24	large branches and small trees begin to sway; crested waves form on inland waters
strong breeze	25-31	large branches continuously moving, electrical wires whistle, clouds of dust are raised
moderate gale	32-38	whole trees move, walking is hampered
fresh gale	39-46	twigs and small branches break, walking is difficult
strong gale	47-54	blows roofing slate off, litters ground with broken branches
whole gale	55-63	trees uprooted, considerable damage
storm	64-75	widespread damage
hurricane	above 75	severe damage

Wind direction can be easily determined. A wet finger held in the wind begins to feel cool on the windward side. A more accurate method is to pick up small pieces of dry grass or leaves and let them fall straight down. Note the direction the wind blows them. A compass will help give a reproducible result that can be compared to other microclimates.

4. Humidity - To find the relative humidity of a place, a simple physical phenomenon is employed--when a liquid evaporates, it cools. The liquid can evaporate faster when there are low amounts of water in the air (the air can absorb and hold more), and the cooling effect is greater.

An instrument called a hygrometer uses this principle to measure relative humidity. A hygrometer is made of two thermometers; one with no moisture on the bulb (dry bulb) and the other with a piece of wet cloth wrapped around the bulb (wet bulb).

One refinement of this instrument is called a sling psychrometer which is a hygrometer that can be whirled to get wet bulb readings faster. Hygrometers and sling psychrometers can be purchased or made.

Once the wet and dry bulb temperatures are known, the relative humidity can be determined by using a relative humidity table.

Relative Humidity

Dry Bulb Temperature °F

Wet Bulb Temperature °F	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
20	37															
25	100	46	10													
30		100	54	22												
35			100	60	31	10										
40				100	64	35	19	5								
45					100	67	43	26	12	3						
50						100	70	48	31	19	9	3				
55							100	73	52	36	24	15	8	3		
60								100	75	55	40	29	20	13	8	
65									100	77	58	44	33	24	17	12
70	interior numbers indicate									100	78	61	47	36	28	21
75	relative humidity										100	79	63	50	39	31
80												100	81	65	52	41
85													100	82	66	54
90														100	82	68
95															100	83
100																100

5. Miscellaneous Equipment -
   Compasses: to determine wind directions, direction of slope, exposure of buildings, etc.
   Soil chemistry kits, percolation test cans, rain gauges: other chemical and physical factors of a place can be correlated with other microclimatic data.
   Increment borer: to age the trees of a particular habitat and to see what effects the microclimates have had on the growth pattern of the plants there.

Suggestions for Microclimate Studies

1. Forest Succession - Ecological succession is the process by which ecosystems naturally change over time. For example, a predictable series of stages will succeed each other on an abandoned farm. After a few years, grasses and other small plants will dominate the area, but tall weeds like asters and goldenrods soon follow. Shrubs like hawthorn, viburnum and blackberries later invade the area. As a result the soil is cooled, is more able to hold moisture, and the litter layer is thickened. The conditions then become right for sun-loving trees like poplars, aspens, and pines, to germinate and grow. These add more organic matter and also shade out the grasses and shrubs. Actually, they produce enough shade so that young poplars, aspens, or pines cannot survive! As older trees of this stage die, younger trees of that same species do not replace them. But other trees like oak, hickory, maple, beech, and hemlock can tolerate the shade. In fact, they require richer and cooler soil in order to germinate. These trees then take over. They stabilize the ecosystem because young trees of this successional stage can replace dead trees of the same species. This more stable stage is the final one, and is called a climax community.

   In summary, the physical factors associated with a microclimate will determine what plants can live there. (The combination of microclimatic conditions and plant life determine what animals can live there.) These living things then modify their environment and the microclimate. In doing so, they often make the environment less favorable to themselves but more favorable to another community of plants and animals. Each stage brings about its own demise.

   Succession can be investigated through microclimate studies. Simply measure the abiotic factors in each successional area available for study, i.e.; meadow, shrub zone, low trees, and tall (climax community) trees. Measurements might include wind speed, light intensity, humidity, and the temperature of the soil, ground surface and the air at several intervals above the ground.

   The study could be supplemented with other investigations. For example, soil pH, soil nutrients, soil litter (weight per area), earthworms or spiders (per area), and diversity indexes could be correlated with the microclimate data. Types of plants and animals observed in each successional area have become specially adapted to that area. Observe or collect the predominate species of an area and try to find out what those adaptations are.

   Remember to prepare a table to record your data before doing the study.

2. Plant and Animal Adaptations for Microclimates - Although plant life helps determine the microclimate of a place, the mircoclimate determines what plants (an animals) can be found there! What adaptations do these plants and animals have that make them well-suited to the microclimate they are found in?

   This question could be investigated by considering one abiotic factor at a time. As an example, consider light.

   Choose a site where light intensity changes rapidly over a short distance. The ecotone between a woodlot and a grassy area would be excellent. Measure the light intensity at various environments; grassland, shrubs, small trees, mature forest. At each site examine the predominant plants, looking carefully for adaptations to the lighting conditions at that site. Shape, size, thickness, color, and arrangement of leaves are some factors that should be studied. Develop a table for recording your results. Record also any evidence of the effects of lighting conditions on the distribution of animals in the area.

   Similar studies could be conducted that would investigate adaptations for humidity or wind conditions.

3. Finding a Comfortable Spot - A fun way to apply microclimate studies directly to our personal needs is to "find the most comfortable spot." On a very hot day, or on a very cool one, have students determine where the best outdoor place would be to have a picnic or to sit for a while. Equipment is used to measure the temperature, humidity, and wind speed in several potential spots. The "best" spot on a warm day should have a cool temperature, some breeze, and low humidity. Students should back up their decision with hard data. Eating a sack lunch at the group's chosen spot would be an appropriate follow-up activity.

   By the way, Victor Olgyay of Princeton University says in Design With Climate that a "comfort zone" ranges from 62 to 82 °F and has 18 to 77 percent relative humidity. For high temperatures or humidities, breezes are necessary. How about a contest among groups to find a place that is closest to the middle of Olgyay's ranges?

4. Microclimates and Solar Energy - What side of your building gets the greatest amount of heat from the sun? What slopes get the most? A microclimate study using thermometers is easily conducted to find the answers. (Because the sun's arc is to the south, as it moves east to west, south sides of buildings and slopes with southerly exposures are usually warmest.)

   The amount of solar energy absorbed is also related to the angle of the slope. What seems to be the ideal slope angle for collecting a maximum of the sun's energy? Does the optimal angle change with the time of day? Does it change with the time of year? How can we apply this information to solar collector designs or landscaping changes?

5. Microclimates and Energy Conservation - Which side(s) of the school or home get(s) the most winter wind, and therefore lose(s) more heat?

   This problem can be investigated through a study of the wind speeds and directions in and around the building in question. Local terrain and landscaping will vary from place to place and will affect the wind pattern.

   Once the wind characteristics at the study site are known, some landscaping could be done to divert wind away from the building. Landscape changes should also take into consideration the heat that could be gained on the sunny sides of the building in both winter and summer (see also #4).

   Before planning any wind-break landscaping, why not examine the effects of wind-breaks? This can be done by measuring wind speeds in front of, in, and at various distances behind any wind-break. Then graph the distances vs. wind speeds. What kinds of trees or other materials (walls, hills, berms, other buildings) break the wind best? What effects do various heights have?

6. Wind Machines - Is there a site on your school or home property that would be a good place for capturing wind energy? Find out by measuring wind speeds at possible sites at various times. If any site has average wind speeds of at least 5 to 7 miles per hour, then there is a good place for a wind machine!

7. Snow and Insulation - Many living things depend on snow or even ice to insulate them from sub-freezing temperatures.

   The insulating effects of snow are easily observed. On a sub-freezing day measure the temperature of the snow at surface level and again at various depths in the snow. Be sure to record the air temperature along with the other data. If possible, measure the soil temperature below the snow and compare it to the soil temperature of an exposed piece of ground.

8. Phenology - This is the study of relationships between climate and the timing of biological events that occur on a periodic basis, such as flowering or hibernation. Many of such biological events are regulated by microclimatic conditions.

   The relationship between microclimate and a phenomenon such as an opening maple bud can make an interesting study. The study could be approached at least two ways. One way is to locate two or more places that have different microclimates, such as a north slope and a south slope, or a hilltop and a hollow. Measure the relevant microclimatic data and note the date and/or time that events (for example, maple buds opening) occur in each location. What conclusions can be drawn regarding the relationship of climate to the biological events?

   Another way to study phenology is to note biological events, such as dandelions blooming earlier in one area than in another. Then measure the microclimatic factors that might be the reason for the phenomenon occurring earlier in one place than in another.

Some other phenological events worth considering include flower blooming, seed germination, budding, sap flow, fruiting, color changes in leaves, dropping of leaves, fish spawning or nesting, and aquatic insect emergence.

9. Heat - The fact that different temperatures are found at different heights can be illustrated by measuring temperatures at chosen height intervals and then graphing the results. Try comparing the stratification in the classroom to that outdoors, or compare the layering above a field with that above the parking lot.

   Temperature stratification also occurs in most deep bodies of water and can be determined with a thermistor and enough wire to reach bottom.

10. Hourly and Seasonal Variations - What microclimatic changes occur as a day goes by? A year? Check the changes in air and soil temperature, humidity, and lighting conditions. How do plants, animals, and man respond to these changes?

11. Jello Animals - This activity is great for young students on a cold day. The object is to have the children become aware of the existence of microclimates without having to use any scientific equipment.

    A package of Jello or gelatin and one jelly cup (like tartar sauce or cream is served in at restaurants) for each participant is needed. Mix up the gelatin and pour equal amounts into each little cup. Explain to the students that they are to find the warmest outdoor place to put their Jello animal so that it won't "freeze". Keep one cup in a very cold place as a "control". Once the control gels, all animals should be retrieved. Animals that are the most fluid had the best caretakers! Where did they keep their animals? What made those places warmer than the places where animals froze? Why do animals burrow in the ground, or stay below the snow, or hibernate underground in winter?

    Have fun eating the Jello critters if they are still relatively clean.

    On a warm day, try to keep "ice animals" from melting.

12. Eyeballing Microclimates - Eyeballing microclimatically different areas is often very easy. For example, when there is a light snow that only sticks to the unpaved areas but melts immediately on the street, we know that the street is warmer. Why?

    Take a look at various places and environments the next time there is a light frost. At times the frost is much heavier in some places than in others. Why? What causes heavy fogging in some places while others have no fog? Why does the snow melt faster on some slopes or locales than others? What causes the snow to drift where it does? Why does a particular flower or tree bloom or leaf out sooner in one area than in another?

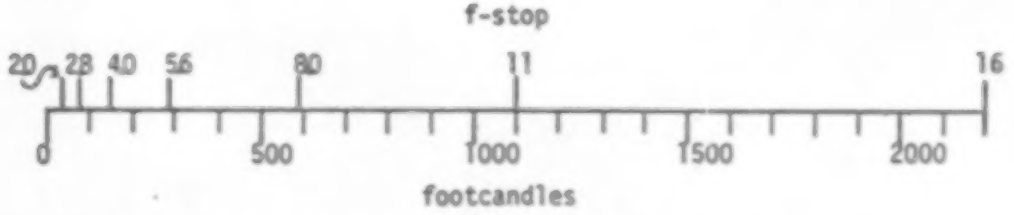
    Answers to these and other questions require an examination of microclimates. In many cases these conditions can be eyeballed and discussed without having to use any equipment.

Solar Constant?

The amount of energy coming from the sun varies so little that until recently scientists could detect no fluctuations. Our immediate earthly concern is not so much to accurately measure the energy coming from the sun but to measure the energy reaching the earth's surface. Clouds and even the atmosphere of the clear sky filter or reflect a tremendous amount of the incoming solar energy. The energy that finally penetrates to the earth's surface is the energy available for use in our collectors. That's what we can heat with.

Accurate, and costly, instruments are available to measure that incident insolation. We can approximate those measurements by use of a standard light meter. With a light meter we can measure the intensity of the light in footcandles. We can then convert those footcandle measurements into heat energy measurements of BTU/hr/ft^2. A light meter which reads directly in footcandles would be the easiest to use.

Most photographer's light meters and most cameras with built-in light meters do not, however, read directly in footcandles. Typically their readings are shutter speeds and f-stops for pre-set film speed settings. To use such a meter first set the film speed at ASA 100. Then set the shutter speed at 1/60 sec. Next select the appropriate f-stop for the existing light conditions. Now, from the chart below, read the number of footcandles that correspond to the f-stop.



Once you have determined the number of footcandles of incident insolation you are ready to calculate available heat energy. One footcandle is equal to 0.0051 BTU/hr/ft^2. This means that for every footcandle of measured light energy there is 0.0051 BTU of heat energy available each hour for each square foot of surface which is perpendicular to the incoming rays of the sun.

Now, armed with your light meter and formula (available energy = footcandles x 0.0051 BTU/hr/ft^2), you are ready to design a study and collect and tabulate some data. Here are some questions you might try to answer:

Is the available solar energy constant?
Are there variations within a day, from day to day, from season to season?
Can you calculate an average rate of energy flow for one particular day?
Can you calculate a total amount of energy received for one particular day?
How does a cloudy day compare to a sunny one?

To answer these questions you will not only need to collect some data, but also to tabulate it in some useful way. You will have to decide whether to use a table of numbers, a bar graph, a line graph, or some other technique.

Would this information be useful in designing a solar collector? Could it help you decide how large to build your collector? What other information would you need to help you design your collector?

Alternatives
by Jim Wakefield

Alternatives began as an interdisciplinary search into the economic and environmental viability of various energy sources. The groundwork for the study had been laid the previous year through the efforts of our industrial arts teachers in a club program titled "Alternative Sources of Energy." This program was expanded to encompass the building of a number of new devices and the use of the equipment and expertise of the science staff to gain data on design efficiency. A variety of activities were planned to achieve community and student energy awareness and consciousness in support of the alternatives search.

North Middle School provides forty minutes per day as a club period which permitted the option of a volunteer status for "Alternatives" members. Initially three clubs were available to the students. One dealt with the design and building of the prototypes, one with the scientific testing and administrative aspects of the program, and one with the necessary publicity to provide the entire student body with information on club progress.

In the fall enthusiasm was high, all clubs filled to capacity, and we began the year with forty interested students. The fall was filled with the many frustrations of researching, designing and building. Work was done on a solar cooker, solar distiller, a flat plate collector, and a passive hydraulic water pump. We encountered problems of limited vandalism and proper placement of equipment to gain good data and had to cope with these unforeseen problems all year. Mid year we began experimentation with parabolics, and progressed from a simple and inefficient hot dog cooker, to a more complex and very efficient one, and finally to a yet untested prototype of a parabolic water heater. Other projects which followed from our research to the design and construction mode included a device for testing dead air space between windows as an insulator, a corrugated metal collector, glauber salts as a heat storage medium, and fresnel lenses. We collected a quantity of data from the solar distilling apparatus utilizing a solar meter and tested for the effect of ambient temperature, sunlight, and various dissolved materials on internal water temperature. Our results gave us much insight into necessary future design changes.

Early in the fall, we began a fruitful relationship with a representative of the Philadelphia Electric Company. With her help, we organized an energy forum for January which included speakers representing coal, oil, nuclear, solar and hydroelectric options. Due to weather conditions, the forum was cancelled and rescheduled several times, but finally held in April. The presentation was given to 200 North Middle School students and a small contingent invited from West Chester's two other middle schools. She also helped us to gain a consultant to aid us in surveying energy usage at North. He toured the school with several students and prepared us for future studies on the efficiency of the building. "Alternatives" was invited to present is findings to a group of fifty gifted students from the Chester County Intermediate Unit as part of a day at Limerick Atomic Generating Station on Sun Day. Ten students were involved in the

display and presentation.

The "Alternatives" program at North was one of success for students and staff. On numerous occasions, the staff would share its varied talents and aid in a specific task. The students gained a feeling of positive group accomplishment, speaking often of the frustrations of working together toward a goal. They felt they had learned much about themselves as they relate to people they are forced to work with, and the importance of individual talents as a contribution to the eventual goals of the group.

Alternate Energy E-Lab I and II
by Jaqueline Blum

1976-77

The activities of the Alternate Energy E-Lab can be clearly shown in three phases.

The first phase consisted of research and planning. Our core solar team, made up of one administrator, three teachers, four community residents, and three student representatives traveled to other solar sites to study and question existing methods in operation. The majority of the time between February and May was spent on collecting information, sorting ideas and discussing various systems according to our specific goals. Blueprints of our solar lab and solar collector were drawn up by our committee.

The second phase was concerned with introducing energy education to our students. The entire fifth and third grades were most actively involved in contributing to the solar energy project as well as studying energy. They constructed solar energy savers, experimented with their own systems, researched and made comparisons of the kinds of energy. They wrote to energy agencies and local businesses for information. In May and June the entire school from kindergarten to fifth grade saw various demonstrations on energy from community agencies. The entire school became aware of our energy experiment and the need for the experiment. The children of Faust were motivated enough to support the solar project by collecting labels and raising funds.

The third phase came at the closing of the school year. The teachers, students and community residents, working as a team, staked out, prepared the footings, and poured a concrete foundation for the solar lab. Solar collectors were started and to date two collectors have been assembled.

At the start of the new school year, 1977-78 we plan to begin wall construction on top of the foundation.

The fourth phase will consist of finishing the lab and collectors in cooperation with the High School Industrial Arts students.

1978-79

We have been planning, organizing and building our Solar Energy Lab for the past three years. During our third year, we were far enough along in the construction of the lab, to turn our attention towards preparing and implementing an energy curriculum for each grade level, K-5.

Each grade level chose a topic concerning energy. The curriculums were developed and taught this year as a pilot program. Kindergarten and first grades taught the children about Plants and the Sun. Second grade studies Wind and Energy. Third grade discovered Transportation and Energy. Fourth grade developed an introduction for studying work, force and energy. Fifth grades continued the overall study of energy that included items from grades K-4 through extended projects.

Sun Week was used as a venicle for culminating and sharing all that was learned during the year. Each grade level showed displays, put on plays, set up sharing and activity stations, showed projects, and in general, shared their knowledge. Community people came in to speak about various subjects concerning energy and the environment. The year for Faust was one in which co-operation and teamwork was at its best! Teachers carpooled, children at different ages shared knowledge and the community became aware of Faust's committment to teach our children about their environment.

Our solar lab was another indication that Faust teachers, parents and community businessmen were committed to learning about energy and improving our environment. The lab has progressed to the point where the collectors are ready to be mounted, the siding is on and electrical work is finished. We anticipate that our dream of an environmental laboratory will be realized during the 1979 school year!

Editor's Note:

In May of 1980 The Robert A. Capron Environmental - Energy Laboratory was formally dedicated. It now serves as a valuable learning resource not only to Faust Elementary School students but to students from across the school district and to the community at large.

BIOCONVERSION

The search for renewable energy sources has lead directly to the sun and indirectly to the sun by way of its products. The products of most interest to us here are plants, animals, and their wastes. Some plant products, such as wood from trees, can be burned directly to provide heat. Sometimes it is useful to decompose dead plants and animals to generate methane gas which can in turn be burned to provide heat. And other times plant and animal products are eaten to provide bodily energy.

TEACHING NOTES

Composting

Here is a simple and fairly direct way of sensing the energy released in that slow combustion process called decay. All that is needed are some fresh lawn clippings, some space to pile them, and some time to let them work. The procedures of this activity can vary from being qualitative to being very quantitative, depending on whether a hand is used to sense the warmth in the center of the pile or whether sophisticated electronic thermisters are used to monitor micro variations in pile temperature. Pick the technique that suits your students' needs and your available equipment.

Marsh Gas

Methane is continually being produced in small quantities in the mucks underlying most bodies of water. Here we suggest several ways to observe the products of anaerobic decomposition. Methane, or marsh gas, is one of those products. A note of caution: A teacher in one of our workshops was dubious when we claimed he could find methane in the creek. He stood knee deep in the muck and churned his feet to release a large quantity of gas. When he lit a match to test for methane, he quickly earned the nickname of "Sizzlin' Sam".

Marsh Gas Observations

Use this as one possible format for recording your observations.

Tree Energy Fact Sheet

These two pages provide much basic information that can be used in a wide variety of math oriented activities. Concepts such as the BTU, cords of wood, burning efficiency, energy equivalents, and cost per BTU are used extensively.

The first page lists 133 species of trees commonly occurring in North America. With each tree is listed its density and the energy available per cord of air dry wood. The available BTU's were calculated by using the formula footnoted at the bottom of the data sheet, consider these as estimates only.

BTU values stated in other sources do not always agree with each other, nor with this list. Two trees of the same species growing under differing micro-climatic condtions will most likely show differing densities and therefore differing energy contents. Consequently, as you perform your calculations, don't assume any more than 3 significant figures. In some cases 2 significant figures might be more reasonable. If your tree is not on the list and you don't know its density, the easiest alternative would be to find a similar or closely related tree and use its BTU data.

The first chart on the second page tabulates and compares data from several different fuels. Of most economic interest is the final column "$/BTU x 10^6". This is what it costs to buy one million BTU's of energy in fall, 1979, in the Philadelphia area.

Considering the times, it would be wise to adjust those figures to your own locale and date. First find your current energy costs per unit of fuel and adjust the "$/unit" column. Then multiply "$/unit" by "units/BTU x 10^6". Your answer will be your adjusted "$/BTU x 10^6".

The "Heating Efficiences" table tells you how much of your energy purchase you can expect to actually be able to utilize. These data are probably the least reliable of all the information on these two pages. The factors affecting efficiency are legion. They include the particular brand of heater used, the age of the heater, the level of heater maintenance, the proficiency of installation, the outside windspeed, the outside temperature, and others. The data can, however, provide some useful comparisons. Keep in mind that efficiency here refers only to the heater's ability to use the energy it receives. No cinsideration is given to the energy it took to cut and store the wood, or to the transmission losses of electricity, or to the mining costs of coal, or to any other "outside" factors. Those outside factors could lead to some very interesting comparisons in the light of net energy analysis, if you would like to delve further.

The core of the "Data/Formula" section is the formula: cordage=circumference squared x height ÷ 2,000. This formula was first devised theoretically by assuming the burnable portion of a tree to be roughly the shape of a cone. Knowning the formula for the volume of a cone (volume = area of base x height ÷ 3) and that a standard cord typically contains 80 cubic feet of solid wood, the formula is easily derived, but with a divisor of approximately 3,000 instead of 2,000. The adjustment has been made based upon actual experience with cut and stacked trees and upon comparison with other cordage estimation techniques in use by foresters. This estimation seems to provide reasonable results for most trees.

Now to the use of the data, here are some directions we've taken it. After dividing the students into teams of two or three, we ask them to find a tree, estimate its height, measure its circumference, and identify it. The teams are then asked to use the cordage formula to estimate how much wood their trees contain. Using the "Heat Available" chart, each team can convert the cordage figure to a BTU figure. Now the teams can multiply their "BTU's x 10^6" by the "$/BTU x 10^6" from the "Comparative Fuel Data" chart to get an economic worth for the trees in question.

As an example, consider a Northern Red Oak tree 45' tall and 5' in circumference:

$$\text{Cordage} = \frac{5^2 \times 45}{2{,}000} = .56 \text{ cords}$$

$$\text{Heat Available} = .56 \times 21.6 \times 10^6 = 12.1 \times 10^6 \text{ BTU}$$

$$\text{Value of Tree} = 12.1 \times 5.00 = \$60.50$$

Now ask the students if there might be more valuable ways to use that tree: for lumber, for shade, for aesthetic reasons,as wildlife habitat.

The "Heating Efficiencies" table can be used to calculate the cost of useful BTU's and thereby more appropriately compare energy costs. Divide "$/BTU X 10^6" by "Energy Efficiency" to get the cost of one million useful BTU's from your particular fuel/heater combination.

For example: Which is cheaper, electricity used to run a heat pump, or wood burned in a fireplace?

$$\text{Electricity} = \frac{18.00}{2.00} = \$9.00$$

$$\text{Wood} = \frac{5.00}{.10} = \$50.00$$

By these figures, wood is not such a bargain. If that wood was used in an air-tight stove the balance would be a little different:

$$\text{Wood} = \frac{5.00}{.50} = \$10.00$$

And if you cut your own wood from your own land, it all looks even better.

One real value of this type of analysis is that it allows you to introduce some hard quantities to values clarification activities that might bog down for lack of information.

Height Estimation Techniques

Here are a dozen ways to estimate the heights of trees or other objects. You will need this technique to completely utilize the Tree Energy Fact Sheet. The techniques progress from the simple to the relatively complex. The estimation accuracy also improves as you move from the first to the last of the techniques, though an experienced observer using a simple technique may be more accurate than the neophyte with his clinometer and trig tables.

Coffee Can Calorimetry

With this technique you will be able to experimentally determine the energy content of various fuels, crudely at least. There are many inefficiencies and heat losses with this procedure but you will be able to get data useful for comparison within your own class. We have tried burning wood, alcohol, corn curls, potatoe chips and many other materials. Some burn well, others don't. Some things, like corn curls, can surprise you. Try not to burn holes in your table tops; try not to fill the air with fairy soot from burning plastic; and try not to explode dry test tubes. With a little care there should be no problems.

In addition to the simple calorimeters described in the activity sheet, you will need some graduated cylinders to measure the volumes of water in the test tubes, a sensitive balance (triple-beam) to measure the fuel weights, and thermometers to measure the water temperatures.

All the measurements called for in the activity should be made in metric units (ml, $^{\circ}$ C, gm). Consequently, the results (cal, cal/gm) are also metric. Should you wish to convert to English measure, please consult the Appendix.

Project GOAT

All the students (about 50) in the Upattinas School participated in this project. Because the kids ranged from kindergarten to grade 12, their involvement was based upon their ability levels. Terry Burlingame and Ed Hess were the teachers primarily involved.

Composting

Most people know that warm blooded animals can "burn" food to heat their own bodies. But can other organisms also create heat? Here's a simple experiment you can do to find out.

Collect a bushel or so of fresh lawn clippings. Pile them somewhere outdoors where they won't be disturbed for several days. You have just created a compost pile, that is, a mixed pile of organic matter in the process of decay. Gardeners use compost to enrich the soil of their planting beds. After several days have passed, check the temperature of the center of the pile. This can be done simply by sticking your hand into the pile, or can be more accurately measured by using a thermometer.

To refine your experiment, try running several variations at the same time. You might use dry grass, fresh grass, fall leaves, or garden cuttings. You could also mix a little topsoil or older compost with some of your piles. The way you collecte your data can also be varied. Try taking temperature readings at various levels in the pile and at set time intervals from the time you start the pile.

Pile Composition	Temperature of Pile											
	Day 1		3		5		7		9		11	
	Center	Edge	C	E	C	E	C	E	C	E	C	E

Marsh Gas

The natural gas we use to heat our homes, burn in our stoves, and power many industrial operations is a fuel of ancient origin. Millions of years ago the earth was partly covered by vast swamps containing tremendous amounts of vegetation. As these plants died and fell one atop the other, thick layers of decaying organic matter began to accumulate. Often these organic layers were covered by layers of mud and silt and sand cutting off the supply of oxygen to the decay bacteria. With no available oxygen, the anaerobic bacteria could take over. The anaerobes can live without free oxygen. As anaerobic decay continued, several waste products were produced, among them were hydrogen sulfide, oil, and natural gas. Often these materials were trapped underground and we can today draw them off for our own use.

Even today these processes continue, unfortunately on a much, much reduced scale. We can observe them though. First find a marshy, mucky, stagnant spot with dead plants and crud in the process of decay. Look for oil on the surface, not the bright rainbow colored refined oil, but a chalkier, duller surface scum. Check also for the tell-tale odor of hydrogen sulfide, the familiar rotten-egg odor. If it is not immediately noticeable, stir the bottom muck, then sniff. Now try a simple test for natural gas or methane. Locate a bubble that has come from the bottom muck. Hold a lighted match near it. If it is methane it should burn in a quick small flair. Be careful not to disturb too much methane at once. You could create a small explosion or risk burning yourself. The genus of bacteria typically responsible for this type of activity is Methanobacterium.

This type of methane production is also known to occur in man-made land-fills. Some communities have begun to experiment with techniques to capture the methane for human use. Can you speculate how they might do this?

Methane is also produced at many sewage treatment plants. The liquid sludge is contained in an air tight container and allowed to decompose anaerobically. The methane that is produced is then drawn off and usually used to power some of the treatment plant processes.

Animal manures from feed lots are being used in similar methane digesters. The resultant methane gas is then used to augment the fossil natural gas we now use.

Can you find places in your own locale where methane is being produced by natural processes?

Area there any methane digesters operating in your vicinity?

Another interesting place to look for naturally produced methane is inside living trees. Seemingly healthy hardwood trees growing in soggy soils will occasionally be infested with Methanobacterium. An increment bore or drill will be needed to penetrate to the heartwood of prospective trees. Be ready to check the slightly pressurized gas for methane by trying to ignite it!

Marsh Gas Observations

#	Date	General Site Location and Description	Natural Oil of Decomposition	Hydrogen Sulfide Odor	Methane Flair
1.					
2.					
3.					
4.					
5.					
6.					

HEAT AVAILABLE FROM AIR DRY WOOD (20% H_2O BY WEIGHT)

SPECIES	DENSITY*	BTU x 10^6/CORD**	SPECIES	DENSITY*	BTU x 10^6/CORD**
Alder, red	.45	15.4	Larch, western	.52	17.8
Apple	.60	20.6	Laurel, California	.62	21.3
Ash, black	.49	16.8	Locust, black	.69	23.7
blue	.58	19.9	Madrone, Pacific	.74	25.4
green	.56	19.2	Magnolia, cucumbertree	.48	16.5
Oregon	.55	18.9	southern	.50	17.2
white	.66	22.6	Maple, bigleaf	.54	18.5
Aspen, bigtooth	.39	13.4	black	.57	19.6
quaking	.38	13.0	red	.54	18.5
Baldcypress	.51	17.5	silver	.47	16.1
Balsam poplar	.34	11.7	sugar	.56	19.2
Basswood, American	.32	11.0	Mulberry	.61	20.9
Beech, American	.56	19.2	Oak, black	.61	20.9
Birch, gray	.51	17.5	bur	.64	22.0
paper	.55	18.9	California black	.64	22.0
sweet	.65	22.3	cherrybark	.68	23.3
white	.53	18.2	chestnut	.66	22.6
yellow	.55	18.9	laurel	.71	24.4
Buckeye, yellow	.40	13.7	live	.88	30.2
Butternut	.36	12.3	Oregon white	.56	19.1
Catalpa	.47	16.1	overcup	.63	21.6
Cedar, Alaska	.44	15.1	pin	.63	21.6
Atlantic white	.35	12.0	post	.67	23.0
eastern red	.44	15.1	red, northern	.63	21.6
incense	.35	12.0	red, southern	.59	20.2
northern white	.31	10.6	scarlet	.67	23.0
Port Orford	.40	13.7	swamp chestnut	.67	23.0
western red	.30	10.3	swamp white	.72	24.7
Cherry, black	.47	16.1	water	.63	21.6
pin	.41	14.2	white	.73	25.0
Chestnut, American	.43	14.7	willow	.69	23.7
Cottonwood, black	.35	12.0	Osage orange	.85	29.2
eastern	.45	15.4	Pine, eastern white	.34	11.7
Dogwood, flowering	.81	27.8	jack	.43	14.7
Douglas-fir, coast	.45	15.4	loblolly	.51	17.5
interior west	.50	17.2	lodgepole	.38	13.0
interior north	.48	16.5	longleaf	.54	18.5
interior south	.46	15.8	pitch	.52	17.8
Elm, American	.46	15.8	pond	.56	19.2
rock	.63	21.6	ponderosa	.38	13.0
slippery	.53	18.2	red	.41	14.1
white	.52	17.7	sand	.48	16.5
Fir, balsam	.34	11.7	shortleaf	.51	17.5
California red	.38	13.0	slash	.59	20.2
grand	.35	12.0	southern	.56	19.2
noble	.39	13.4	spruce	.44	15.1
Pacific silver	.43	14.7	sugar	.36	12.3
subalpine	.32	11.0	Virginia	.48	16.5
white	.42	14.4	western white	.38	13.0
Gum, black tupelo	.46	15.8	Poplar, yellow	.42	14.4
sweet	.54	18.5	Redwood, old growth	.40	13.7
Hackberry	.53	18.2	young growth	.35	12.0
Hemlock, eastern	.38	13.0	Sassafras	.51	17.5
mountain	.45	15.4	Spruce, black	.40	13.7
western	.45	15.4	engleman	.35	12.0
Hickory, bitternut	.66	22.6	red	.41	14.1
mockernut	.72	24.7	sitka	.37	12.7
nutmeg	.60	20.6	white	.37	12.7
pecan	.66	22.6	Sycamore, American	.46	15.8
pignut	.75	25.7	Tanoak	.64	22.0
shagbark	.72	24.7	Tamarack	.53	18.2
shellbark	.69	23.7	Tupelo, black	.50	17.2
water	.62	22.3	swamp	.50	17.2
Honeylocust	.66	22.6	water	.50	17.2
Holly	.64	22.0	Walnut, black	.51	17.5
Hophornbeam	.72	24.7	Willow, black	.34	11.7
Hornbeam, American	.68	23.3			

*Density is a measure of mass/volume, the density of water is 1 at 4° C.

**The approximate BTUs of energy available per cord were calculated as BTU/cord = 8,600 BTU/lb (oven dry wood) X 62.32 lb/ft^3 (at a density of 1.00) X density of individual species of wood X 80 ft^3/cord (solid wood) X .80 (energy penalty for 20% moisture content) = 34.3 X 10^6 X density of individual species of wood. Note also that BTU X 10^6 = millions of BTUs.

COMPARATIVE FUEL DATA

FUEL	BTU/UNIT	UNITS/BTU X 10^6	1 CORD WOOD EQUIVALENT*	$/UNIT**	$/BTU X 10^6 **
Coal	2.5 X 10^7 BTU/ton	.04 ton	.80 ton	110/ton	4.40
#2 Fuel Oil	1.4 X 10^5 BTU/gal.	7.1 gal.	140 gal.	.90/gal.	6.50
Gasoline	1.3 X 10^5 BTU/gal.	7.7 gal.	150 gal.	1.10/gal.	8.50
Natural Gas	1.1 X 10^3 BTU/ft^3	910 ft^3	18,000 ft^3	.0056/ft^3	5.10
Electricity	3.4 X 10^3 BTU/KWH	290 KWH	5,800 KWH	.062/KWH	18.00
Wood*	2.0 X 10^7 BTU/cord	.05 cord	1 cord	100/cord	5.00

*Figures for wood here tabulated are broad averages.
**These figures are appropriate to the Philadelphia area in fall, 1979 and should be adjusted to your own locale and time.

HEATING EFFICIENCIES

HEATER TYPE	ENERGY EFFICIENCY*
Heat pump	1.50-2.00
Electric radiant	1.00
Home gas furnace	0.85
Home oil furnace	0.65
Stoker-fired coal	0.60
Air-tight wood stove	0.50
Simple box stove	0.30
Fireplace/circulator	0.20
Fireplace	0.10

*These efficiencies refer only to heater energy use not to the total fuel cycle. Percent efficiency can be determined by multiplying these data by 100.

DATA/FORMULAE

Standard Cord = stack of wood, 4' X 4' X 8' = 128 ft^3; an average "standard cord" contains 80 ft^3 of solid wood.

Approximate cordage contained in one tree can be estimated after measuring (in feet) the tree's height (H) and circumference at breast height (C):

$$\text{Cordage} = \frac{C^2H}{2,000}$$

1 lb. oven dry wood (0% water) contains approximately 8,600 BTU, regardless of the type of wood. BTU/cord is primarily a function of wood density and water content. Some softwoods may have as much as a 10% energy advantage per pound because of the resins they contain. A typical pound of air dried hardwood will contain approximately 6,900 BTU/lb, while softwood will contain 7,600 BTU/lb.

DATA USE/INTERPRETATION

Please bear in mind that the numbers utilized here are approximations or averages. Individual trees within a species may vary considerably; in fact, the data from the sources listed below did not always agree. Energy costs vary from region to region and will most certainly rise. Heating efficiencies are dependent on the particular burner involved, how well it's tuned, how well it's installed. The cordage formula is a theoretical approximation but corresponds well with other estimation techniques currently in use. The information here should still allow for some broad comparisons. Have fun!

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HEIGHT ESTIMATION TECHNIQUES

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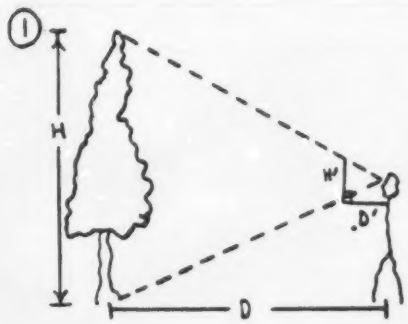
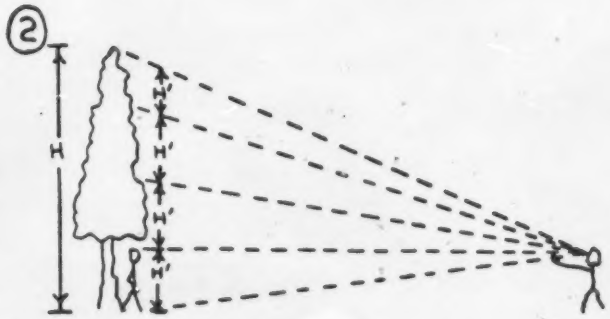
① 

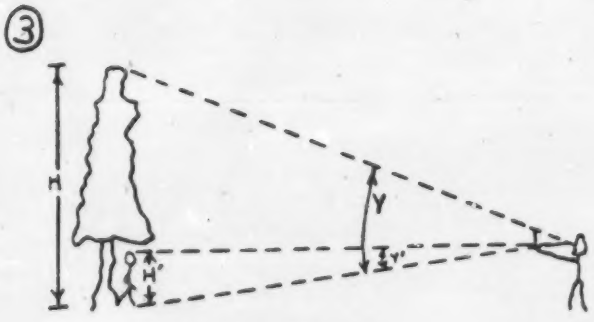
$H = D$ (WHEN $H' = D'$)

HOLDING A STICK (H') (EQUAL IN LENGTH TO YOUR REACH (D')) AT ARM'S LENGTH, BACK AWAY FROM OBJECT TO BE MEASURED UNTIL BOTTOM AND TOP OF OBJECT ALIGN WITH BOTTOM AND TOP OF STICK. HEIGHT OF OBJECT (H) EQUALS DISTANCE FROM OBJECT.

② 

$H = H' \cdot$ (# OF INCREMENTS)

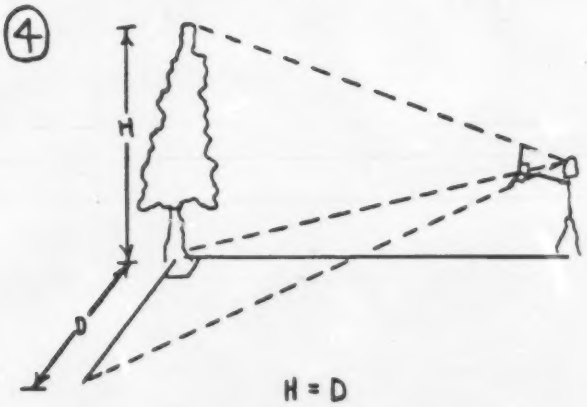
MEASURE APPARENT HEIGHT OF INDIVIDUAL (H') ON STICK HELD AT ARM'S LENGTH. COUNT NUMBER OF INCREMENTS REQUIRED TO REACH TOP OF OBJECT. HEIGHT OF OBJECT (H) EQUALS HEIGHT OF INDIVIDUAL TIMES THE NUMBER OF INCREMENTS.

③ 

$H = \frac{H'Y}{Y'}$

ON SCALE (CENTIMETERS OR OTHER STANDARD MEASURE) HELD AT ARM'S LENGTH, MEASURE APPARENT HEIGHT OF INDIVIDUAL (Y') AND APPARENT HEIGHT OF OBJECT TO BE MEASURED (Y). MEASURE REAL HEIGHT OF INDIVIDUAL (H'). REAL HEIGHT OF OBJECT (H) EQUALS REAL HEIGHT OF INDIVIDUAL TIMES APPARENT HEIGHT OF OBJECT DIVIDED BY APPARENT HEIGHT OF INDIVIDUAL.

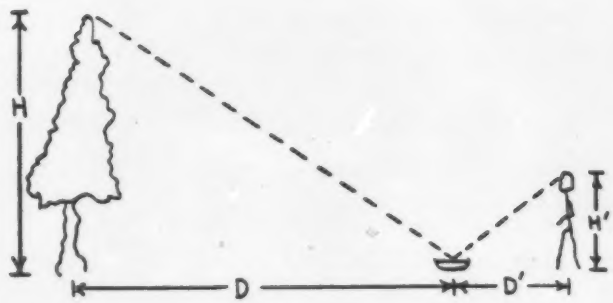
④



$H = D$

HOLD STICK AT ARM'S LENGTH WITH TOP OF STICK IN LINE WITH TOP OF OBJECT. MARK ON STICK THE LINE OF SITE TO BASE OF OBJECT. STILL AT ARM'S LENGTH, ROTATE STICK TILL HORIZONTAL. SIGHT SPOT ON GROUND INDICATED BY TOP OF STICK. SPOT MUST LIE AT RIGHT ANGLE FROM YOUR SIGHTING LOCATION. HEIGHT OF OBJECT (H) EQUALS DISTANCE OF SPOT FROM OBJECT (D).

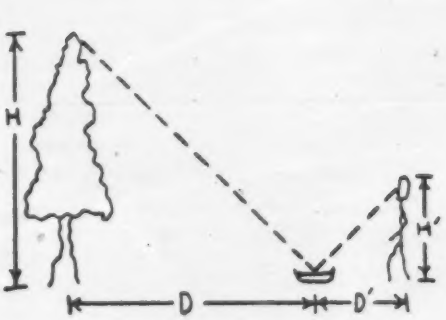
⑤



$$H = \frac{H' D}{D'}$$

PLACE BASIN OF MUDDY WATER SOME DISTANCE FROM OBJECT TO BE MEASURED. POSITION OBSERVER SUCH THAT THE TOP OF THE OBJECT IS VISIBLE IN THE BASIN. HEIGHT OF OBJECT (H) EQUALS HEIGHT OF OBSERVER (H') TIMES DISTANCE FROM BASIN TO OBJECT (D) DIVIDED BY DISTANCE FROM BASIN TO OBSERVER (D').

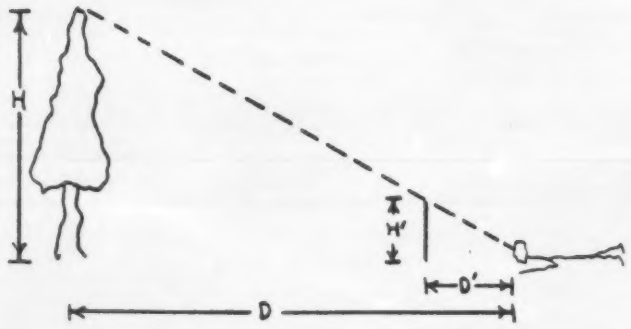
⑥



$H = D$ (WHEN $H' = D'$)

PLACE BASIN OF MUDDY WATER ON GROUND SUCH THAT THE TOP OF THE OBJECT CAN BE VIEWED WHEN THE OBSERVER STANDS HIS OWN HEIGHT (H') AWAY (D') FROM BASIN. HEIGHT OF OBJECT (H) EQUALS DISTANCE (D) OF BASIN FROM OBJECT.

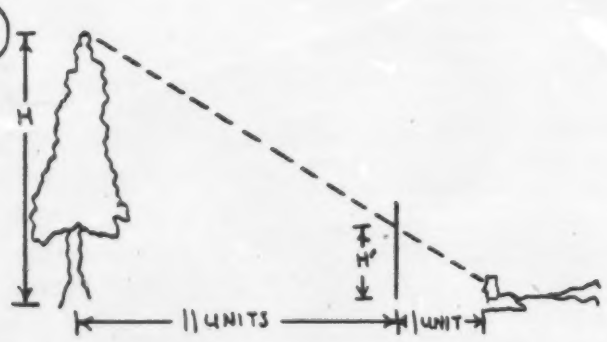
⑦



$$H = \frac{H' D}{D'}$$

PLACE STAFF VERTICALLY IN GROUND. SIGHT FROM GROUND SUCH THAT TOP OF OBJECT AND TOP OF STAFF ALIGN. HEIGHT OF OBJECT (H) EQUALS HEIGHT OF STAFF ABOVE GROUND (H') TIMES DISTANCE FROM OBSERVER TO OBJECT (D) DIVIDED BY DISTANCE FROM OBSERVER TO STAFF (D').

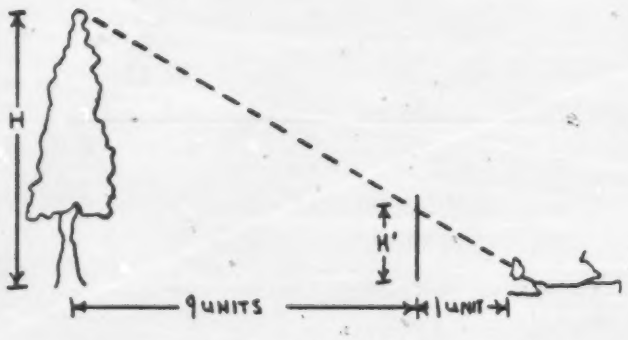
⑧



H (FEET) = H' (INCHES)

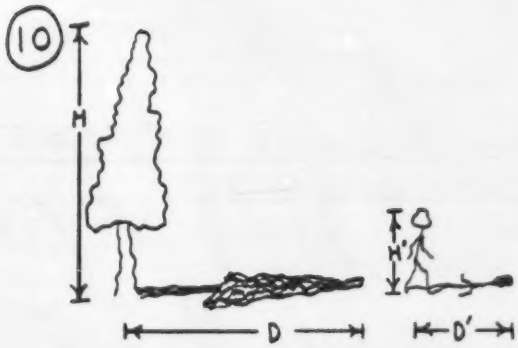
MEASURE 11 UNITS (STEPS, PACES, JUMPS, ETC.) FROM BASE OF OBJECT AND PLACE STAFF VERTICALLY IN GROUND. MEASURE 1 ADDITIONAL UNIT FOR OBSERVATION POINT. SIGHT FROM POINT TO TOP OF OBJECT; MARK WHERE LINE OF SITE HITS STAFF. HEIGHT OF OBJECT MEASURED IN FEET (H) EQUALS LENGTH OF STAFF TO MARK MEASURED IN INCHES (H').

⑨



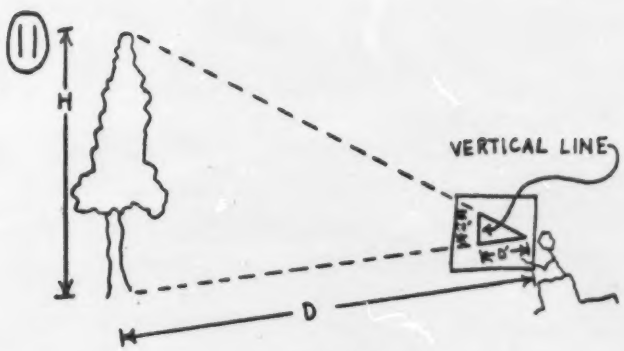
H (METERS) = H' (DECIMETERS)

MEASURE 9 UNITS (STEPS, PACES, JUMPS, ETC.) FROM BASE OF OBJECT AND PLACE STAFF VERTICALLY IN GROUND. MEASURE 1 ADDITIONAL UNIT FOR OBSERVATION POINT. SIGHT FROM POINT TO TOP OF OBJECT; MARK WHERE LINE OF SIGHT HITS STAFF. HEIGHT OF OBJECT MEASURED IN METERS (H) EQUALS LENGTH OF STAFF TO MARK MEASURED IN DECIMETERS (H').



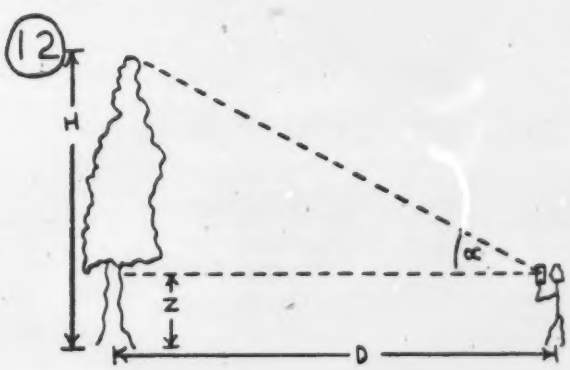
$$H = \frac{H'D}{D'}$$

MEASURE LENGTH OF SHADOW OF OBJECT (D), HEIGHT OF INDIVIDUAL (H'), AND LENGTH OF SHADOW OF INDIVIDUAL (D'). HEIGHT OF OBJECT (H) EQUALS HEIGHT OF INDIVIDUAL TIMES LENGTH OF SHADOW OF OBJECT DIVIDED BY LENGTH OF SHADOW OF INDIVIDUAL.



$$H = \frac{H'D}{D'}$$

PLACE PLANE TABLE VERTICALLY SUCH THAT OBJECT CAN BE SIGHTED ALONG ITS SURFACE. DRAW LINE OF SIGHT TO BASE OF OBJECT. DRAW LINE OF SIGHT TO TOP OF OBJECT. DRAW VERTICAL LINE SUCH THAT IT INTERSECTS BOTH SIGHTED LINES DISTAL FROM THEIR POINT OF INTERSECTION. HEIGHT OF OBJECT (H) EQUALS LENGTH OF VERTICAL LINE (H') TIMES DISTANCE TO OBJECT (D) DIVIDED BY LENGTH OF BASE LINE OF SIGHT (D').



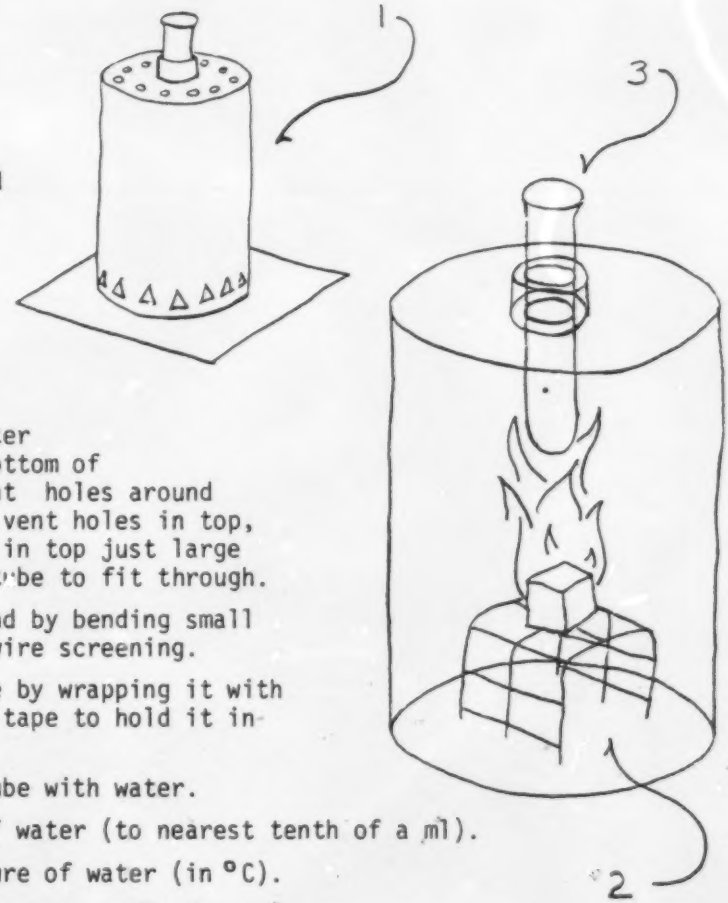
$$H = \text{TAN } \alpha \cdot D + Z$$

MEASURE ANGLE FROM LEVEL TO TOP OF OBJECT (α). MEASURE HEIGHT OF OBJECT TO LEVEL LINE OF SIGHT (Z). MEASURE DISTANCE FROM SIGHTING POINT TO BASE OF OBJECT (D). HEIGHT OF OBJECT (H) EQUALS TANGENT OF ANGLE TIMES DISTANCE TO OBJECT PLUS HEIGHT TO LEVEL.

Coffee Can Calorimetry

Materials:

Coffee can
Large test tube
Duct tape
Wire stand
Metal or asbestos pad
Test fuels
Matches
Thermometer
Balance
Graduated cylinder



Procedure:

1. Prepare calorimeter by cutting out bottom of can, punching vent holes around bottom, punching vent holes in top, and cutting hole in top just large enough for test tube to fit through.
2. Prepare fuel stand by bending small piece of welded wire screening.
3. Prepare test tube by wrapping it with a collar of duct tape to hold it in position.
4. Half fill test tube with water.
5. Measure volume of water (to nearest tenth of a ml).
6. Measure temperature of water (in °C).
7. Weigh fuel (to nearest tenth of a gm).
8. Ignite fuel and immediately place in calorimeter.
9. As soon as the fuel has been consumed, measure the water temperature (in °C); if water boils, start again with less fuel.
10. Calculate the heat transferred to the water:

$$\text{calories} = \frac{\text{final temperature (°C)} - \text{start temperature (°C)}}{\text{volume of water (ml)}}$$

11. Calculate the number of calories in each gram of fuel:

$$\text{cal/gm} = \frac{\text{calories transferred}}{\text{grams of fuel}}$$

Project GOAT
by Terry Burlingame

Project GOAT was a great seed for us in terms of both ideas and the money to try them out. We were able to try some things that we had wanted to do for a long time and develop some new ideas about where we want to go in the future. In less than a year's time we have learned about goats, their feeding and housing needs, their temperments and habits (good and bad) and their abilities at producing milk for the family table. We have observed one of them produce offspring of both sexes and develop into a fresh milking goat. We learned how to build two structures this year, the first a shed built mainly of recycled wood and the second a greenhouse built mainly of wood that we logged ourselves and took to a sawmill. Both structures were built for a fraction of the comparative lumber yard costs. We have also learned how to make the greenhouse more energy efficient by passive heat storage and have bought a generator unit to experiment with a wind-powered backup system on cloudy days. Finally, we have utilized the milk products in many forms (milk, cheese, yogurt, ice cream) and found their production to be less expensive than any available market product. The milk when fresh and cold tastes exactly like fresh cow's milk to unbiased observers.

The seed grows and plans for the future unfold. We are moving to a new place next year, a permanent home which we will build from the ground up on about 5 acres of land. We definitely plan to keep a goat there based on the success of the project on so many levels this year. We plan to dismantle the greenhouse frame and reassemble it at the new place with a permanent fiberglass front face. In it we plan to experiment with sprouted grasses and a legume, birds foot trefoil, which can boost milk production and cut feed costs. We will also test the practicality of our small wind generator as a model for a larger one to run the whole school building. Finally, the things we learned about energy conservation this year will be incorporated into the design of the new place (proper angles and orientation for solar heat, combination wood/fuel heating system) to make it as energy efficient as possible, and a model for a reduced consumption style of living.

APPENDIX

Glossary

Here are a few good words, not all of the good words, but hopefully enough to get you through this book.

Unit Conversions

If everyone used the same type of ruler, we wouldn't need these tables. They don't, sometimes for good reasons, but mostly for reasons of historic coincidence. These tables should allow you to make needed translations. Even though not everyone speaks English, this book has been written entirely in English, I think.

Bibliography

This list could easily get out of hand. I've only listed a very few of my personal favorites. You probably already have your own personal favorites anyway.

Skill/Grade/Discipline Suitability

Look here first if you need an activity at a specific skill or grade level, or in a particular discipline.

Glossary

Active solar system - a solar heat collection system that requires some outside energy to run fans, pumps, valves, etc.

Ampere (amp) - a unit of electric current equal to watts/volts.

Anaerobic decomposition - decay occuring in the absence of free oxygen.

Angle of incidence - the angle which incoming solar radiation makes with a line perpendicular to a collector's surface.

Barrel (bbl) - a standard measure of crude oil equal to 42 gallons.

Bioconversion - the conversion of one form of energy to another by plants, animals, or microorganisms; often refers to the conversion of radiant solar energy to chemical energy by photosynthesis, or to the formation of methane during anaerobic decomposition.

Biomass - the amount of living matter in an area, often referring to that material available for fuel.

BTU (British Thermal Unit) - the amount of heat energy needed to raise the temperature of one pound of water one degree Fahrenheit.

calorie - the amount of heat energy needed to raise the temperature of one gram of water one degree Celsius.

Calorie - 1,000 calories.

Celsius - the metric temperature scale with 0° as the freezing point of water and 100° as the boiling point; °C = 5/9 (°F -32).

Centigrade - Celsius.

Concentrating collector - a device which reflects or refracts the sun's rays onto a smaller area, primarily to create high temperatures in small volumes.

Conduction - the transmission of heat energy from molecule to molecule in a solid.

Convection - the transmission of heat energy by moving matter such as air or water currents.

Cord - a unit of wood cut for fuel equal to a stack 4' x 4' x 8' (128 cubic feet), containing about 80 cubic feet of solid wood.

Dead air space - air space confined between materials and used for insulation (eg. between window panes or within a wall).

Degree day - a unit measuring the coldness of an area, calculated by subtracting the average daily temperature (in °F) from 65°.

EER (Energy Efficiency Ratio) - a measure of the efficiency of an air conditioner calculated as the heat energy removed (in BTUs) divided by the electricity consumed (in kwhs), EER = $\frac{\text{BTU out}}{\text{kwh in}}$.

Efficiency - ratio of useful work (energy output) to total work (energy input).

Electricity - a form of energy and fundamental entity of nature consisting of positive and negative charges.

Energy - the ability to do work.

Entropy - a measure of the disorder or uniformity of a system; energy transfers tend to increase disorder (increase entropy) and reduce the amount of available useful energy.

Fahrenheit - the English temperature scale with 32° as the freezing point of water and 212° as the boiling point; °F = 9/5 °C + 32.

Flat plate collector - a solar collector in which unconcentrated solar radiation is converted to heat on a flat surface.

Footcandle - a unit of illumination equal to one lumen per square foot, very roughly equal to the illumination of a surface one foot from a single candle.

Force - a "push" or "pull", the rate of change in momentum of an object.

Gasoline - a liquid composed primarily of light hydrocarbons refined from petroleum.

Glazing - a clear or translucent cover on a solar collector or window, typically made of glass or plastic.

Heat - a form of kinetic energy resulting from the motion of molecules within a substance.

Heat pump - a mechanical device used to move heat from a cool area to a warm area by alternately evaporating and condensing a fluid within a closed system.

Horsepower - a unit of power equal to 550 footpounds of work per second.

Insolation - the incoming radiation from the sun.

Insulation - a substance which resists the flow of heat.

Joule - a metric unit of energy equal to the force of one newton operating through a distance of one meter.

Kilocalorie - a unit of energy equal to 1,000 calories or 1 Calorie.

Kilowatt - a unit of power equal to 1,000 watts.

Kilowatt-hour (kwh) - a unit of energy equal to 1,000 watts of power operating for one hour.

Lumen - a unit of luminous flux equal to the light emitted in a unit solid angle by a uniform point source of one candle.

Methane - gaseous compound (CH_4), the chief component of natural gas.

Normal - an angle of incidence of 0°, the sun's rays being perpendicular to the plane of the collector.

Number 2 fuel oil - the refined oil commonly used for home heating purposes.

Parabola - a curve mathematically described as being equidistant from a point and a line; in solar applications this produces a reflector which can focus a beam of light on a single point.

Passive solar system - a solar heat collection system which requires no additional energy input for transporting the energy collected.

Pay-back period - the length of time required to completely recoup an investment.

Petroleum - an oily, flammable liquid which is a complex and variable mixture of hydrocarbons.

Power - the rate at which work is done or energy transferred.

Photosynthesis - the process by which plants convert radiant energy into chemical energy.

Resistance heating - conversion of electrical energy to heat by forcing an electric current through a poor conductor.

Return on investment - the ratio of the money saved or earned to the money expended in a particular project, usually expressed as a % per year.

R value - a unit of resistance to heat flow measured as $ft^2/hr/°F/BTU$; the reciprocal of the U value.

Solar energy - the electro-magnetic radiation from the sun.

Solar cell - a device which converts radiant energy directly into electrical energy.

Solar collector - a device which converts radiant energy into heat.

Temperature - the degree of hotness or coldness of an object.

Therm - a unit of energy equal to 100,000 BTUs.

Thermal mass - any object (typically water, brick or rock) used to store heat energy.

Thermodynamics - the study of the relationship between heat and mechanical work.

Thermodynamics, laws of -

1st Law, Conservation - energy can neither be created nor destroyed, but can change form and move from place to place.

2nd Law, Entropy - any use or transfer of energy results in an increase in entropy (disorder), consequently all energy use results in a loss of available, usable energy, and no energy use can be 100% efficient.

Thermosiphon - the natural tendency of warm air or water to rise above colder air or water.

U value - a unit of transmittance of heat measured in $BTU/ft^2/hr/^oF$; the reciprocal of the R value.

Volt - a unit of electrical force or pressure equal to watts/amps.

Watt - a unit of electrical power equal to volts x amps.

Work - the movement of an object through a distance, measured by multiplying the force applied by the distance moved.

UNIT CONVERSIONS

Length
(from x no. = to)

FROM \ TO	IN	FT	CM	M
IN	1	8.3×10^{-2}	2.5	2.5×10^{-2}
FT	12	1	3.0×10	3.0×10^{-1}
CM	3.9×10^{-1}	3.3×10^{-2}	1	1.0×10^{-2}
M	3.9×10	3.3	1.0×10^{2}	1

Mass
(from x no. = to)

FROM \ TO	OZ	LB	GM	KG
OZ	1	6.3×10^{-2}	2.8×10	2.8×10^{-2}
LB	1.6×10	1	4.5×10^{2}	4.5×10^{-1}
GM	3.5×10^{-2}	2.2×10^{-3}	1	1.0×10^{-3}
KG	3.5×10	2.2	1.0×10^{3}	1

Energy
(from x no. = to)

FROM \ TO	JOULE	CAL	KCAL	BTU	WATT HR	KWH	HP HR
JOULE	1	2.4×10^{-1}	2.4×10^{-4}	9.5×10^{-4}	2.8×10^{-4}	2.8×10^{-7}	3.7×10^{-7}
CAL	4.2	1	1.0×10^{-3}	4.0×10^{-3}	1.2×10^{-3}	1.2×10^{-6}	1.6×10^{-6}
KCAL	4.2×10^{3}	1.0×10^{3}	1	4.0	1.2	1.2×10^{-3}	1.6×10^{-3}
BTU	1.1×10^{3}	2.5×10^{2}	2.5×10^{-1}	1	2.9×10^{-1}	2.9×10^{-4}	3.9×10^{-4}
WATT HR	3.6×10^{3}	8.6×10^{2}	8.6×10^{-1}	3.4×10	1	1.0×10^{-3}	1.3×10^{-3}
KWH	3.6×10^{6}	8.6×10^{5}	8.6×10^{2}	3.4×10^{3}	1.0×10^{3}	1	1.3
HP HR	2.7×10^{6}	6.4×10^{5}	6.4×10^{2}	2.5×10^{3}	7.5×10^{2}	7.5×10^{-1}	1

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POWER
(from x no. = to)

FROM \ TO	BTU/HR	CAL/HR	HP	WATT	KW	LUMEN
BTU/HR	1	2.5×10^{2}	3.9×10^{-4}	2.9×10^{-1}	2.9×10^{-4}	2.0×10^{2}
CAL/HR	4.0×10^{-3}	1	1.6×10^{-6}	1.2×10^{-3}	1.2×10^{-6}	8.0×10^{-1}
HP	2.5×10^{3}	6.4×10^{5}	1	7.5×10^{2}	7.5×10^{-1}	5.0×10^{5}
WATT	3.4	8.6×10^{2}	1.3×10^{-3}	1	1.0×10^{-3}	6.7×10^{2}
KW	3.4×10^{3}	8.6×10^{5}	1.3	1.0×10^{3}	1	6.7×10^{5}
LUMEN	5.1×10^{-3}	1.3	2.0×10^{-6}	1.5×10^{-3}	1.5×10^{-6}	1

ILLUMINATION
(from x no. = to)

FROM \ TO	FOOTCANDLE	LUMEN/FT^2	BTU/HR/FT^2	CAL/HR/M^2	WATT/FT^2
FOOTCANDLE	1	1	5.1×10^{-3}	1.4×10	1.5×10^{-3}
LUMEN/FT^2	1	1	5.1×10^{-3}	1.4×10	1.5×10^{-3}
BTU/HR/FT^2	2.0×10^{2}	2.0×10^{2}	1	2.7×10^{3}	2.9×10^{-1}
CAL/HR/M^2	7.3×10^{-2}	7.3×10^{-2}	3.7×10^{-4}	1	1.1×10^{-4}
WATT/FT^2	6.7×10^{2}	6.7×10^{2}	3.4	9.3×10^{3}	1

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Books

Energy Primer: Updated and Revised; R. Merrill and T. Gage; Dell Publishing, Inc., 1 Dag Hammarskjold Plaza, NY, NY 10017; 1978, 256 pp, $7.95.

The best of the broad-based alternate energy information sources.

Home, Inc.; S. Burns; Doubleday & Company, Inc., Garden City, NY; 1975, 252 pp, $6.95.

A look at current economics from the view of the individual household.

Pedal Power; J. McCullagh, ed.; Rodale Press, Inc., Emmaus, PA; 1977, 133 pp, $4.95.

A look at the wide variety of old and new applications of pedal power technology.

Poverty of Power: Energy and the Economic Crisis; B. Commoner; Bantam Books, Inc., 666 Fifth Ave., NY, NY 10019; 1976, 298 pp, $2.75.

Energy and economics from the view of a renowned environmentalist.

Small is Beautiful: Economics as if People Mattered; E. F. Schumacher; Harper & Row Publishers, Inc., 10 E. 53rd St, NY, NY 10022; 1973, 290 pp, $3.75.

Philosophic arguments for appropriate scale, technology, and energy.

Soft Energy Paths: Toward a Durable Peace; A. Lovins; Harper & Row Publishers, Inc., 10 E. 53rd St, NY, NY 10022; 1977, 231 pp, $3.95.

Documentation and proposals for the transition to renewable energies.

Solar Greenhouse: Design, Construction, Operation; R. Fisher, B. Yanda; John Muir Publications, PO Box 613, Santa Fe, NM 87501; 1976, 161 pp, $6.00.

Good introduction on how to do it in a variety of ways.

Solar Home Book: Heating, Cooling, and Designing with the Sun; B. Anderson; Brick House Publishing Co., Inc., Harrisville, NH 03450; 1976, 297 pp, $9.50.

Good introduction to solar heat with excellent follow through on data, calculations, and specifications.

Periodicals

CoEvolution Quarterly; S. Brand, ed.; CoEvolution Quarterly, PO Box 428, Sausalito, CA 94965; $12.00/4 issues/yr.

Lively and far-reaching dialogue from an holistic viewpoint.

Energy and Education; J. Fellows ed.; National Science Teachers Association, 1742 Connecticut Ave., NW, Washington, DC 20009; free, 5 issues/yr.

Continuing update and discussion of curricula, conferences, and the current energy situation.

Mother Earth News; The Mother Earth News, Inc., 105 Stoney Mountain Rd., Hendersonville, NC 28739; $10.00/6 issues/yr.

Down-to-earth alternative lifestyles, environment, and energy.

Penn Energy; Governor's Energy Council, 1625 N. Front St., Harrisburg, PA 17102; free, 12 issues/yr.

Update on Pennsylvania energy concerns; your state may have a similar publication.

Solar Age; B. Anderson, ed.; SolarVision, Inc., Church Hill, Harrisville, NH 03450; $20.00/12 issues/yr.

A good way to keep up on solar.

Worldwatch Papers; Worldwatch Institute, 1776 Massachusetts Ave., NW, Washington, DC 20036; periodic publications, $25.00/yr.

Wide range of global issues, usually environmental, often energy related.

Curricula

Energy Activities for the Classroom; H.L. Coon, M.Y. Alexander, ed's; ERIC Center for Science, Mathematics, and Environmental Education, College of Education, Ohio State University, 1200 Chambers Rd., 3rd Floor, Columbus, OH 43212; 1976, 148 pp.

Selected energy activities for grades K-12 in all curricular areas.

Energy Conservation in the Home; L. Cunard, et al; U.S. Department of Energy, Technical Information Center, PO Box 62, Oak Ridge, TN 37830; 1977, 310 pp.

"An energy education/conservation curriculum guide for home economics teachers."

Energy and Man's Environment: Activity Guide; T.F. Ris, ed.; Education/Research Systems, Inc., 2121 5th Ave., Seattle, WA 98121; 1973, 111 pp.

A K-12 curriculum development program sponsored by The Northwest Electric Utilities, The Washington State Department of Public Instruction, The Oregon State Department of Education, and The Idaho Department of Education.

Curricula (cont'd)

Energy: Options for the Future; T.O. Carroll, Project Director; Institute for Energy Research and W. Averell Harriman College for Urban and Policy Sciences, State University of New York at Stony Brook, Stony Brook, NY 11794.

Series of curriculum guides and topics such as "Food & Energy", "Demand Scheduling & Electric Utilities", "Solar, Wind & Biomass", "Environment", and "Conservation".

Pennsylvania's Energy Curriculum for the Middle Grades; J.J. McDermott, Chairperson; Pennsylvania Department of Education, Box 911, Harrisburg, PA 17126; 1977.

A compilation of various activities and background information, check with your own Department of Education first.

Project for an Energy Enriched Curriculum; developed by The National Science Teachers Association; available from U.S. Department of Energy, Technical Information Center, PO Box 62, Oak Ridge, TN 37830.

A series of 24 instructional packets for elementary and secondary schools, with titles such as "How a Bill Becomes Law to Conserve Energy", "Agriculture, Energy, and Society", "Energy and Transportation", "Mathematics in Energy", and "Energy Transitions in U.S. History".

Science Activities in Energy; prepared by Oak Ridge Associated Universities; available from U.S. Department of Energy, Technical Information Center, PO Box 62, Oak Ridge, TN 37830; 1979.

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Solar Energy Project; developed by U.S. Department of Energy; available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402; 1979.

A technical curriculum written for application at grade levels 7-12, for use in the science disciplines.

Your Energy World; U.S. Department of Energy, Assistant Secretary for Conservation and Solar Application, Office of Marketing and Education, Washington, DC 20545; 1978.

Four packets of activity masters on energy topics.

Suppliers

Brooklyn Thermometer Company, Inc., 90 Verdi St., Farmingdale, NY 11735.

All types of general purpose, specialty, mechanical, and electronic thermometers at all kinds of prices.

Suppliers (cont'd)

EARS - Environmental Action Reprint Service, Box 545, LaVeta, CO 81055.

Mail order books, magazines, and articles; ask for the "Energy Catalog".

Edmund Scientific, 101 E. Gloucester Pike, Barrington, NJ 08007.

Wide range of parts and equipment for the experimeter.

Federal Surplus Property Distribution Center, Bureau of Surplus Property, 2221 Forster St., PO Box 3361, Harrisburg, PA 17125.

Every state has its own distribution center accessible only to schools, fire companies, civil defense, and the like. The prices are incredibly low, the values are variable. Try to find your state's center.

Kalwall Corporation, Solar Components Division, PO Box 237, Manchester, NH 03105.

Parts and supplies useful for homebuilt collectors and student experimentation.

Markson Science, Inc., 565 Oak St., Box 767, DelMar, CA 92014.

General science lab supplies, good electronic thermometer selection.

Scrounge, Anyplace, Your Town, Your State, USA.

Your best source of odd parts and adaptable supplies may just be your own back yard; local businesses and industries often can be very helpful with parts, instrumentation, and expertise.

SKILL/GRADE/DISCIPLINE SUITABILITY

ACTIVITY	SKILL LEVEL*			GRADE LEVEL									DISCIPLINE										Page
	Awareness	Transitional	Operational	4	5	6	7	8	9	10	11	12	Biology	Chemistry	Phys. Sci.	Soc. Studies	Lang. Arts	Math	Phys. Ed.	Ind. Arts	Home Ec.	Art	
Human Energy																							
Pumping Iron	X			X	X	X	-	-	-	-			X						X				6
Human Horsepower Contest		X		-	-	X	X	X	X	X	X	X	X		X			X	X				7
Human Energy Needs		X			-	-	-	X	X	X	X	X	X					X	X		X		9
What's In The Package ?		X			-	-	-	X	X	X	X	X	X					X			X		10
Waste Not, Want Not			X	-	-	-	X	X	X	-	-	-	X			X					X		11
Project POWER			X						-	-	X	X	X	X			X	X			X		12
Electricity																							
Conserving Consumption	X			X	X	X	X	X	X	X	X	X				X					X		18
Rational Rationing	X					-	X	X	X	X	X	X				X		X			X		19
Watt Watching		X				-	X	X	X	X	X	X			X	X		X			X		20
Dim It		X		-	-	-	X	X	X	X	-	-	X		X	X					X		22
Clocks Count		X					-	-	-	X	X	X				X		X			X		23
Wasting Away		X				-	X	X	X	X	-	-			X			X			X		24
In Hot Water		X					-	-	X	X	X	X			X			X		X	X		25
Project Impact			X	-	X	-	-	-							X		X					X	27
Space Heating																							
Draft-O-Meter	X			X	X	X	-	-							X					X	X		35
Thermostat Stats		X		-	-	-	X	X	X	-	-	-			X			X		X	X		36
R Values Important?		X		-	-	-	X	X	X	X	-	-			X			X		X			37
Home Heating Audit		X		-	-	-	X	X	X	X	X	X			X	X		X		X	X		38
ROI		X					-	-	-	X	X	X				X		X		X	X		55
Project DETECT			X				-	-	-	X	X	X			X	X	X	X		X	X	X	57
Solar Energy																							
Several Simple Solar Studies	X			X	X	X	-	-	-						X					X			60
Cardboard Collectors		X		X	X	X	X	X	X	X	X	X			X					X	X	X	68
Doll House Contest		X		-	-	-	X	X	X	X	X	X			X	X				X	X	X	76
Microclimates		X		X	X	X	X	X	X	X	X	X	X		X								77
Solar Constant?		X					-	-	-	X	X	X			X					X			85
Alternatives			X			-	-	X	X	X	-	-			X			X		X			87
Alternate Energy E-LAB I & II			X	X	X	X	X	X	X	X	X	X	X		X			X		X	X	X	89
Bioconversion																							
Composting	X			X	X	X	X	X	X	X	-	-	X	X									95
Marsh Gas	X			-	-	-	X	X	X	X	X	-	X	X									96
Tree Energy		X		-	-	-	X	X	X	X	X	X	X			X		X		X			98
Coffee Can Calorimetry		X				-	-	X	X	X	X	-	X	X	X			X		X			104
Project GOAT			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		105

*For explanation please see the "Introduction" on page 1.